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DesJardien et al.

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(54) **MODULAR AND RECONFIGURABLE
SUPPORT SYSTEM**

(58) **Field of Classification Search**
USPC 269/21; 29/525.01, 525.02, 700
See application file for complete search history.

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(56) **References Cited**

U.S. PATENT DOCUMENTS

5,604,974 A 2/1997 Roberts et al.
5,621,970 A 4/1997 Roberts et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CN 102339069 A 2/2012
CN 102730197 A 10/2012
(Continued)

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OTHER PUBLICATIONS

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State Intellectual Property Office of China Notification of First
Office Action and Partial English Translation, dated Dec. 1, 2016,
regarding Application No. 20140030074.8, 14 pages.

(Continued)

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(57) **ABSTRACT**

An apparatus and method for supporting an object. In one illustrative embodiment, an apparatus may comprise a support structure, a positioning system, and a retention system. The positioning system may be associated with the support structure and configured to position the support structure with respect to a number of linear axes. The retention system may be associated with the support structure. The retention system may be configured to retain a portion of an object and move the portion of the object towards a platform such that the portion of the object substantially conforms to a shape of the platform.

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B23Q 1/25 (2006.01)

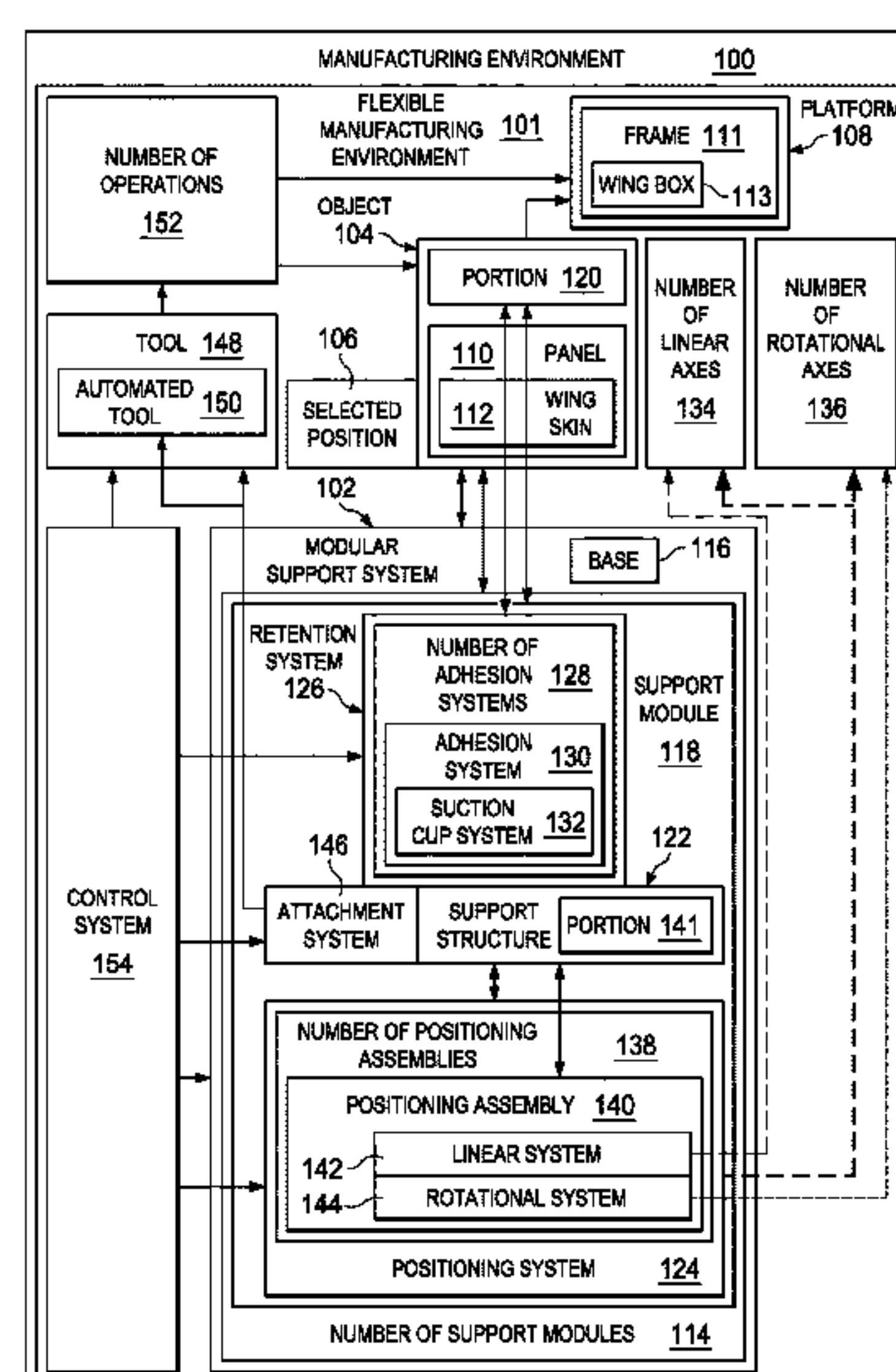
B23P 19/10 (2006.01)

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(2013.01); **B23Q 1/25** (2013.01); **B64F 5/10**
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29/49998 (2015.01)

15 Claims, 23 Drawing Sheets



References Cited

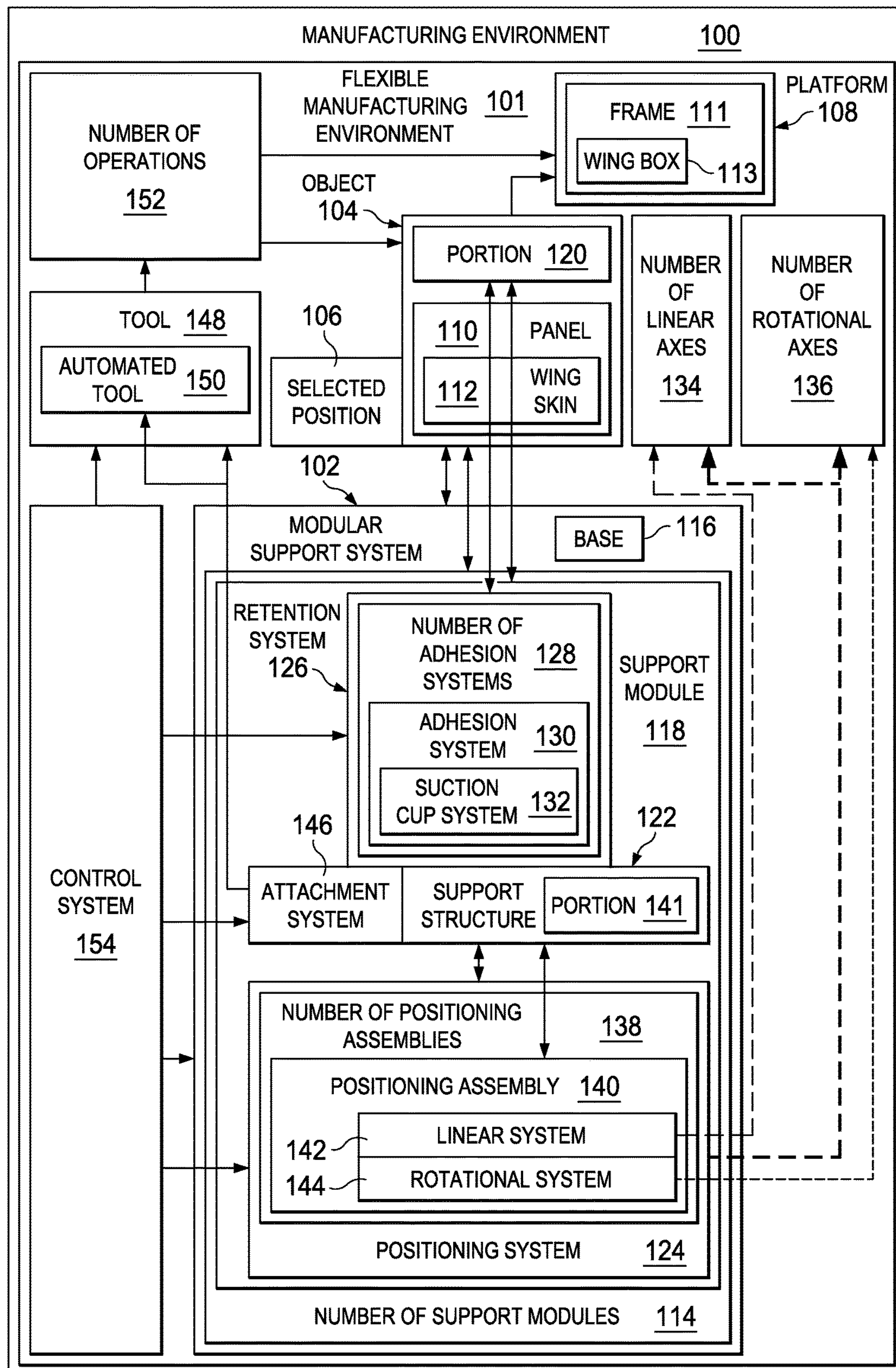
2008/0155807	A1 *	7/2008	Toh	B21J 15/14 29/525.01
2010/0135754	A1 *	6/2010	Weber	B64F 5/10 414/222.04
2012/0130528	A1 *	5/2012	Stark	B23P 19/10 700/114

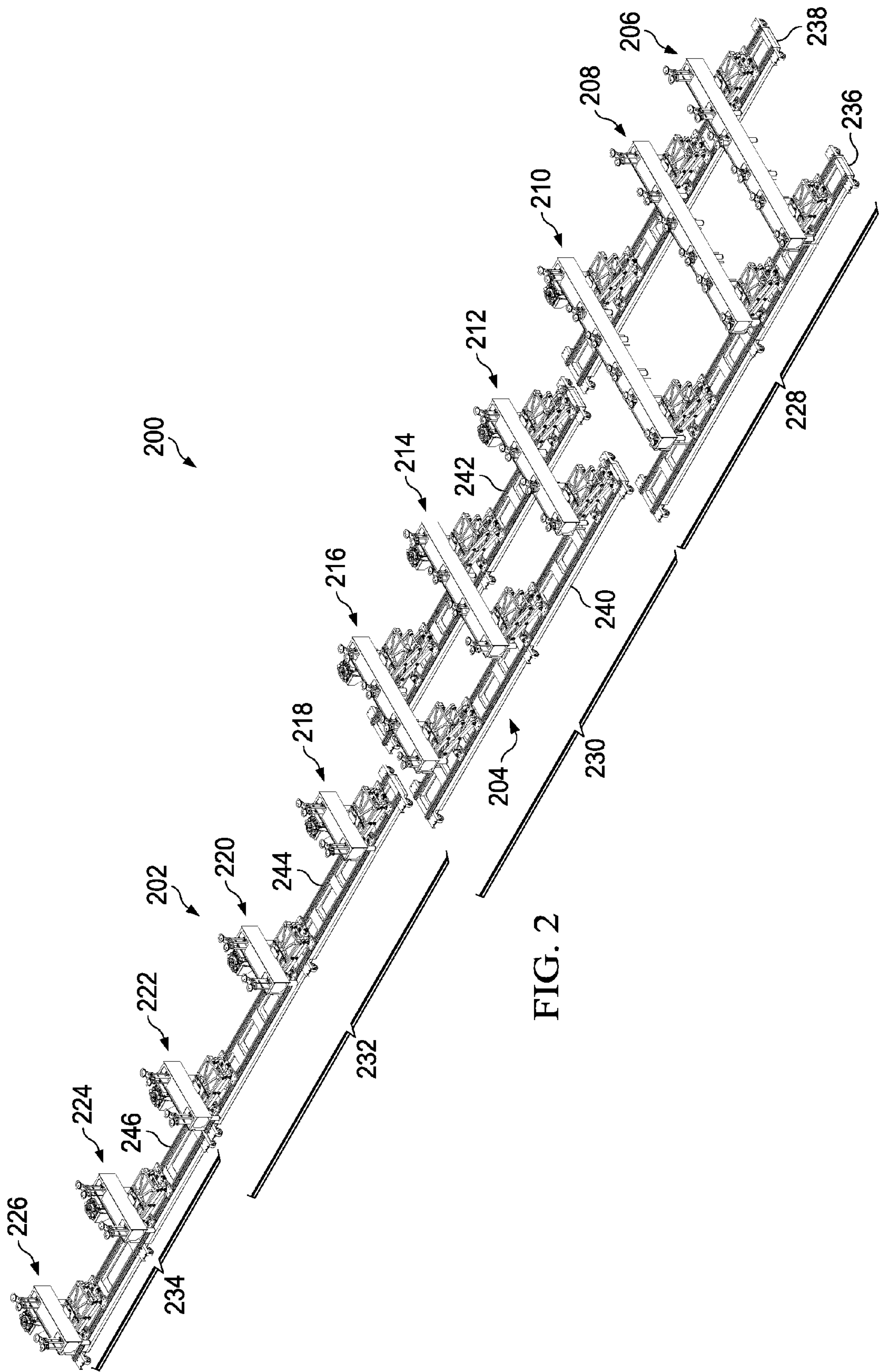
CN	202574627	U	12/2012
DE	102009018991	A1	11/2010
EP	0277423	A1	8/1988
JP	2011148559	A	8/2011
JP	2012131239	A	5/2012
WO	WO03037564	A2	5/2003
WO	WO2011061307	A1	5/2011

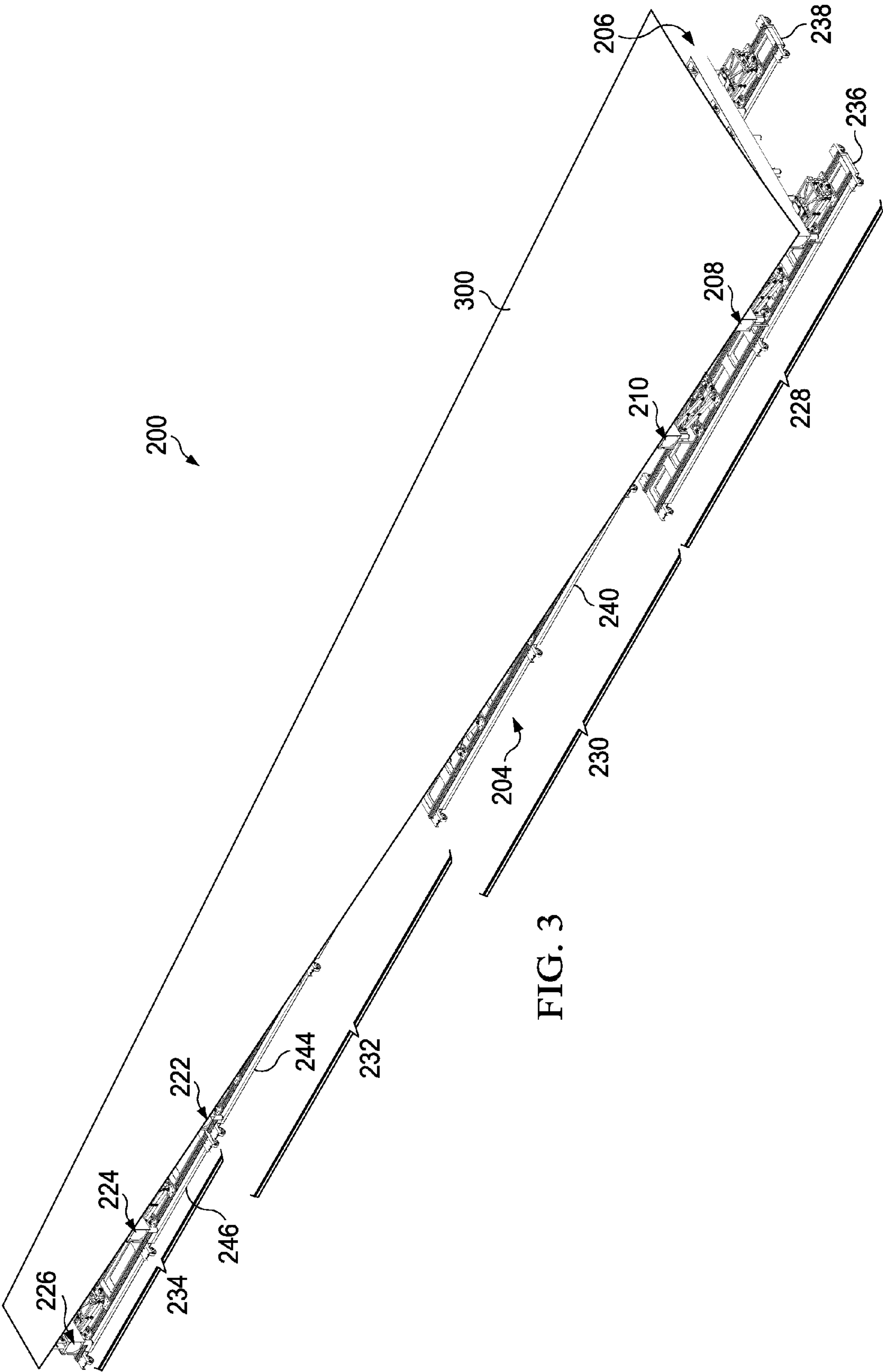
Results of the Partial International Search, dated Sep. 30, 2014, regarding Application No. PCT/US2014/036614, 8 pages.
Japanese Patent Office Notice of Reasons for Rejection, dated Aug. 30, 2017, regarding Application No. 2016-516665, 15 pages.
Canadian Intellectual Property Office Office Action, dated Aug. 24, 2017, regarding Application 2,902,277, 13 pages.
State Intellectual Property Office of PRC Notification of Second Office Action, dated Aug. 11, 2017, regarding Application No. 201480030074.8, 19 pages.

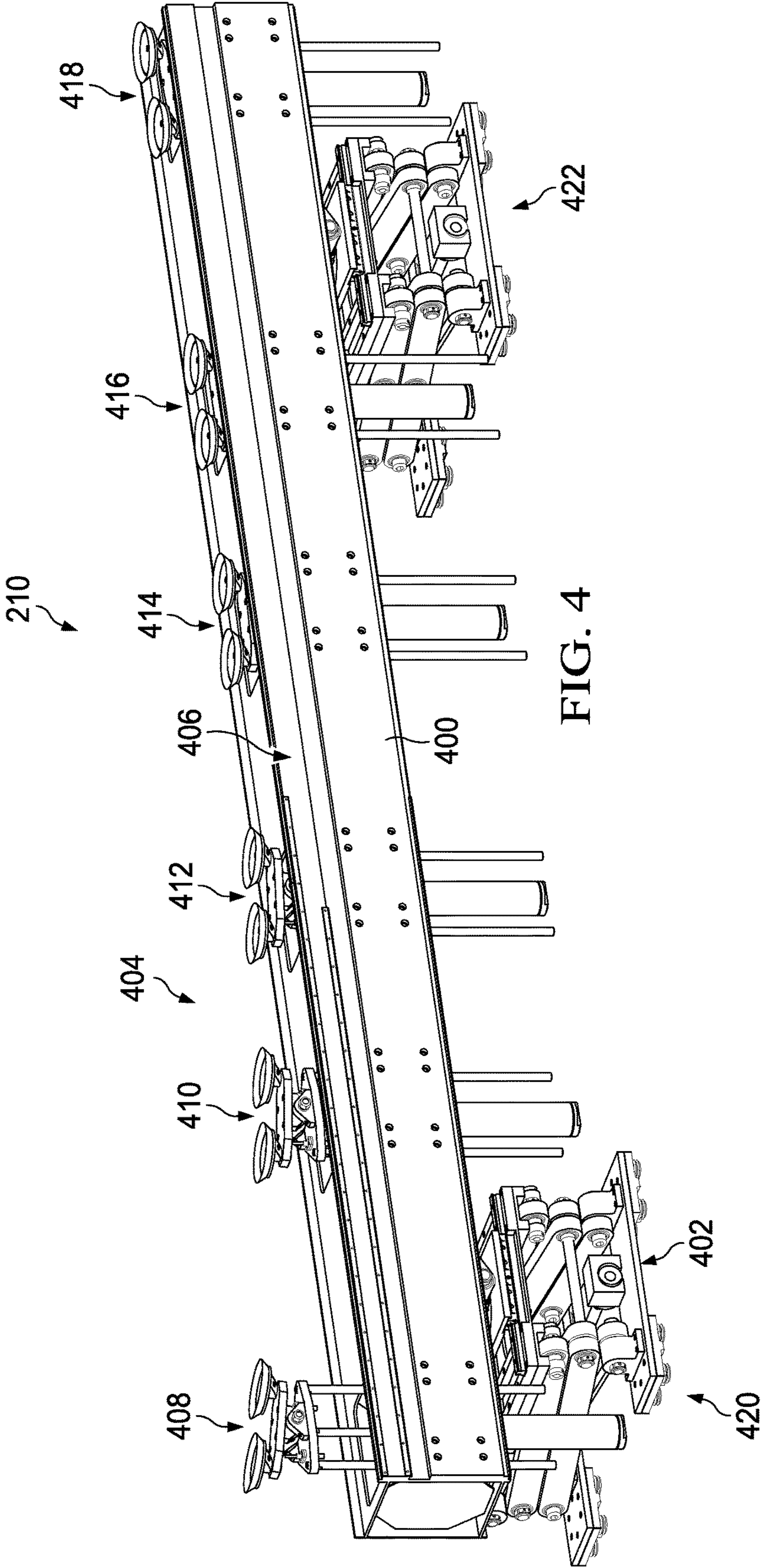
* cited by examiner

FIG. 1









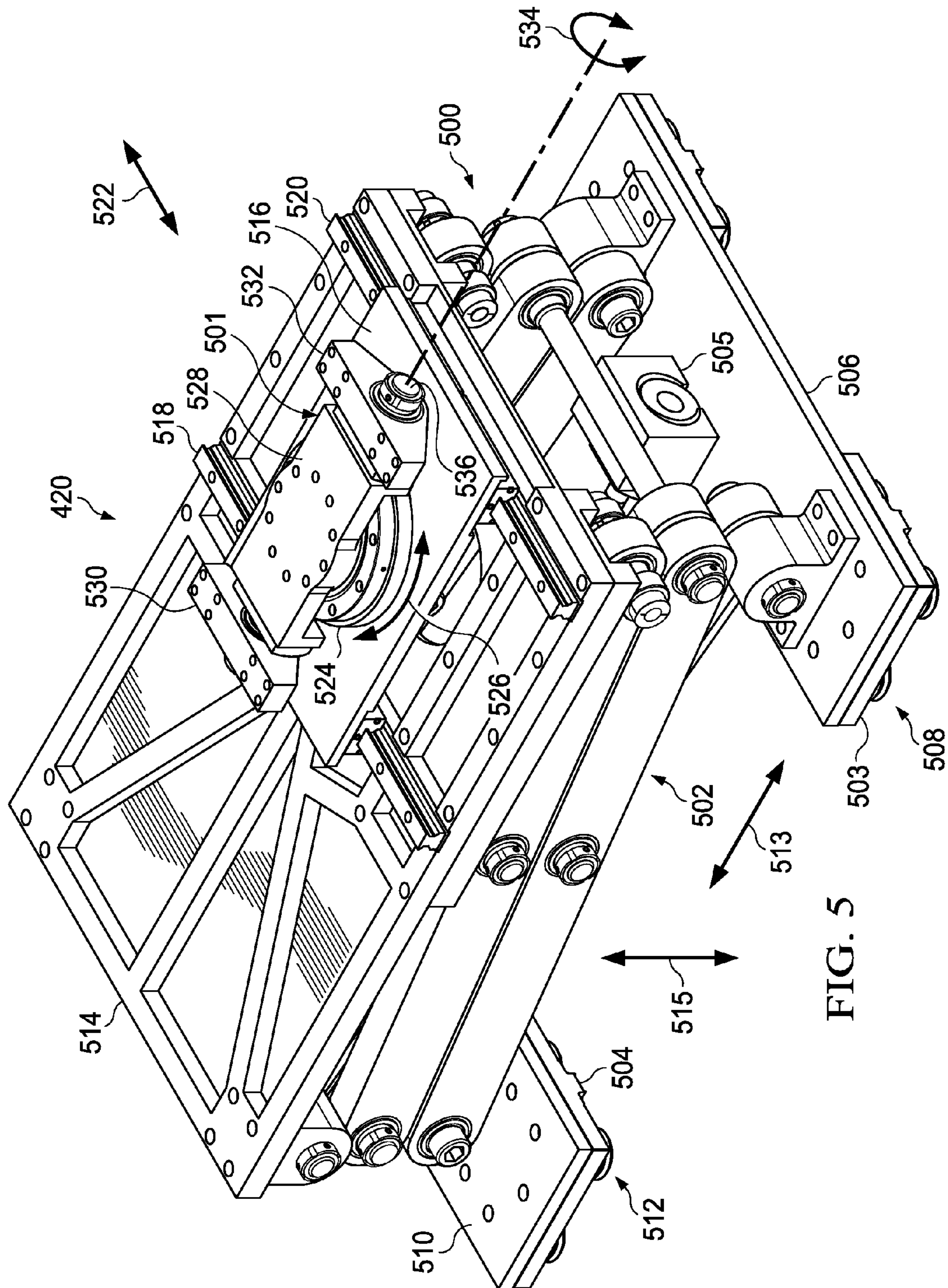


FIG. 5

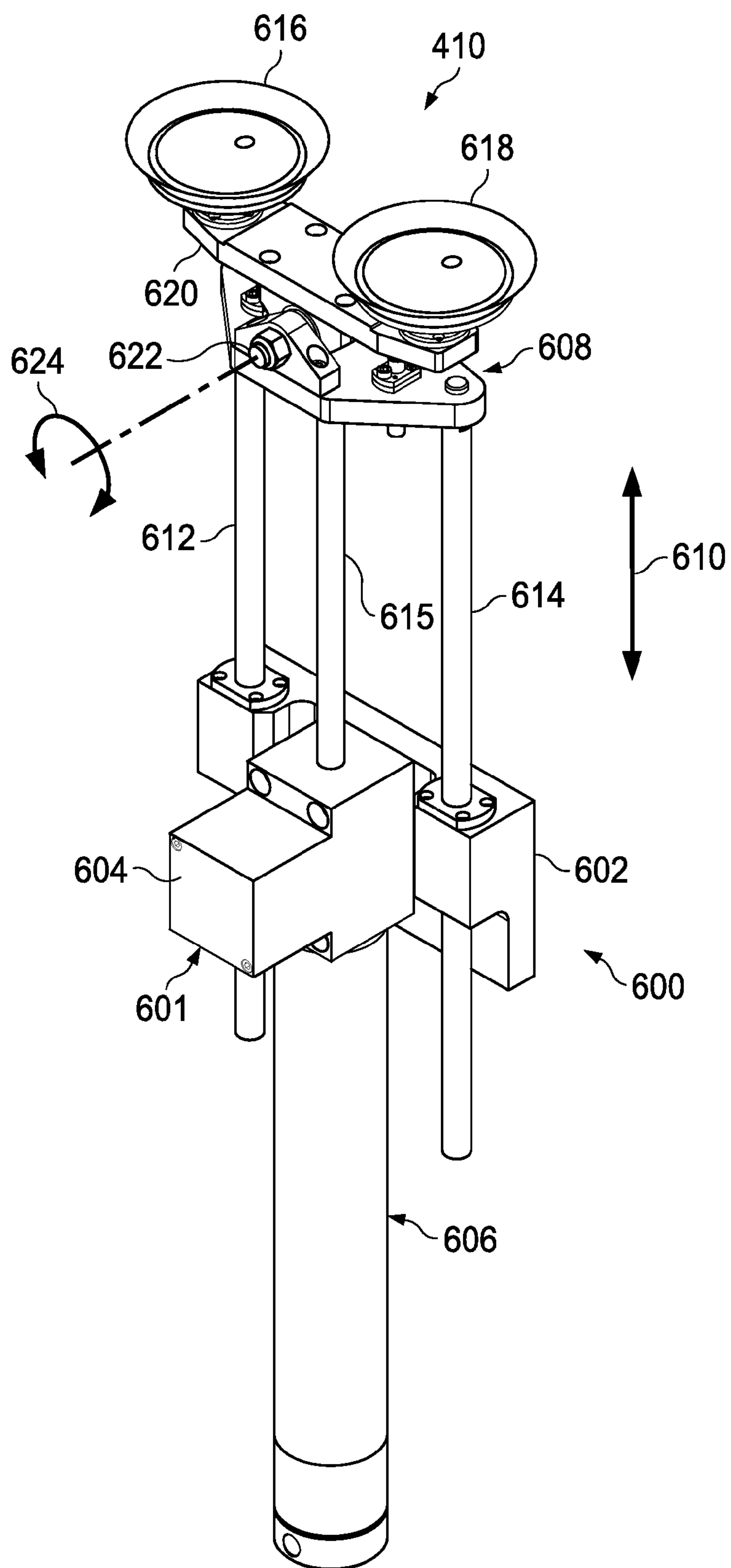


FIG. 6

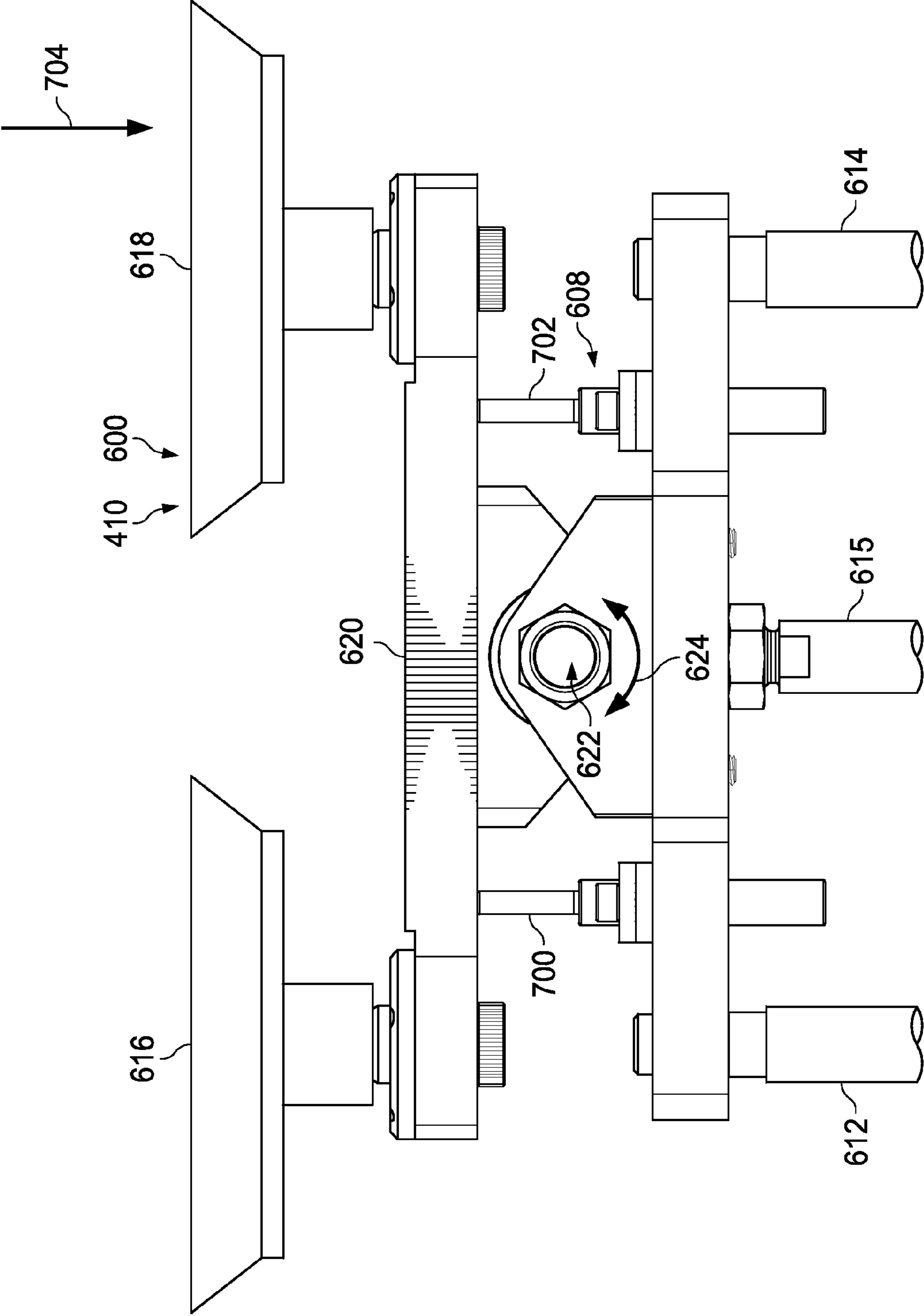


FIG. 7

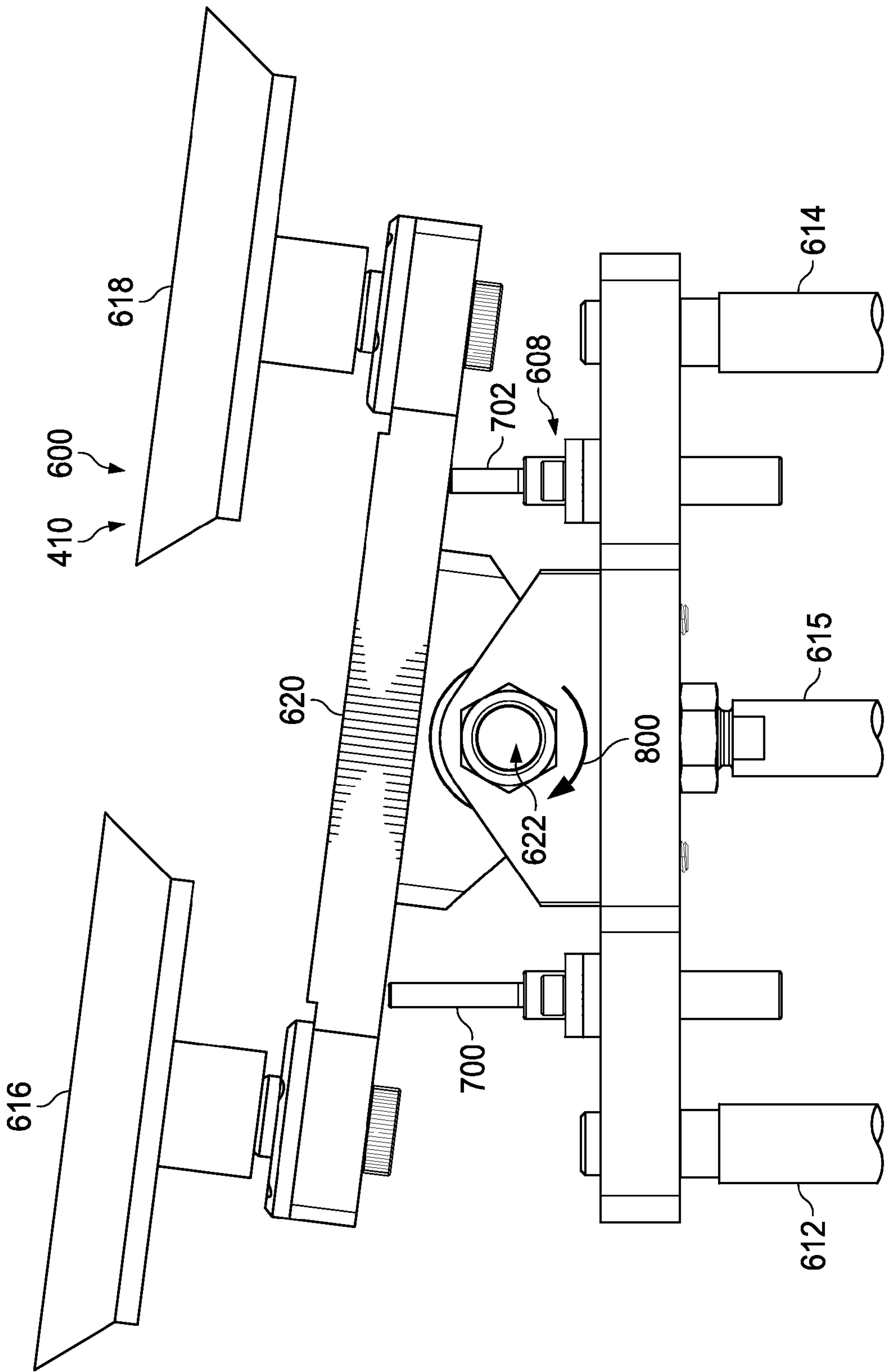
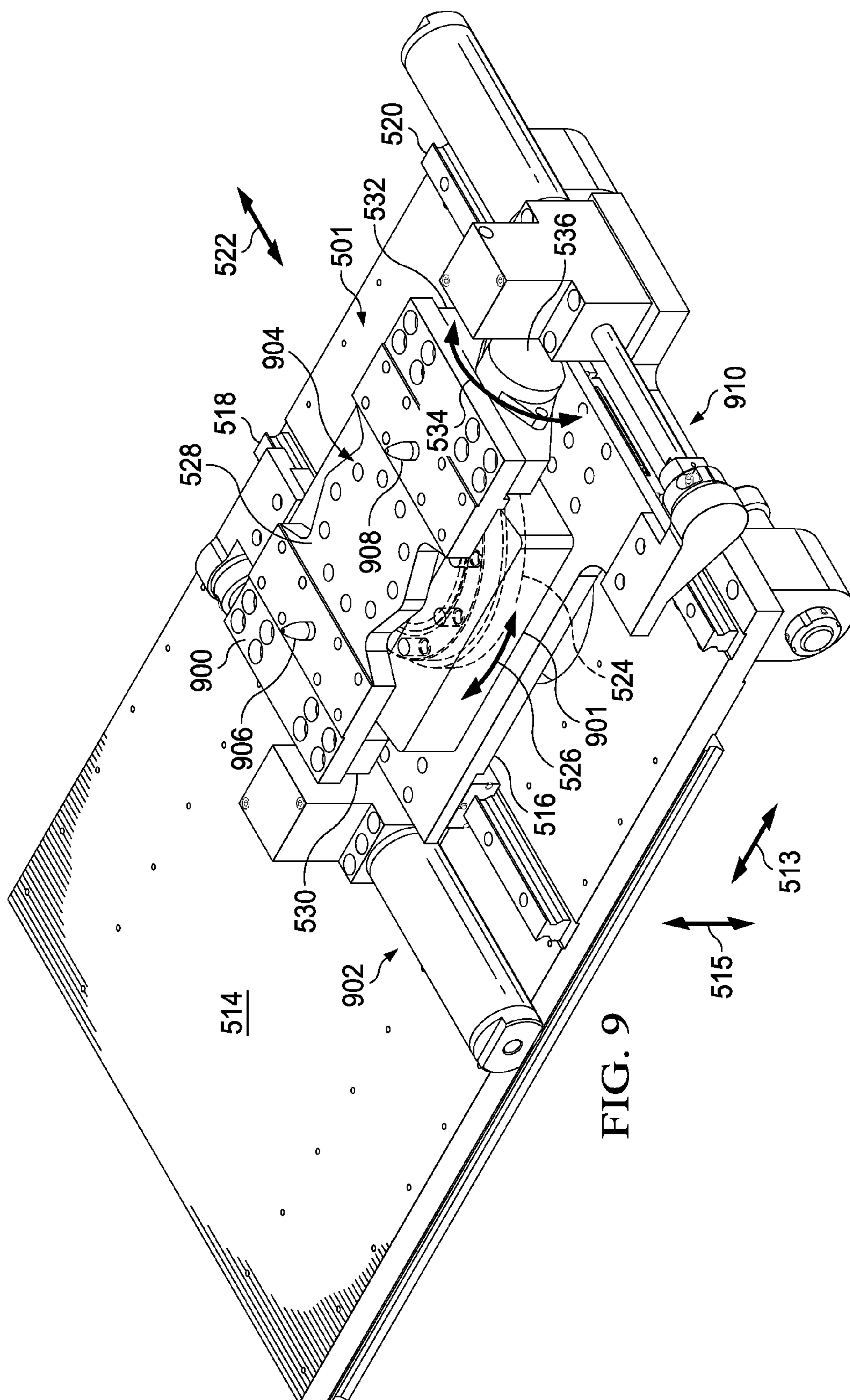
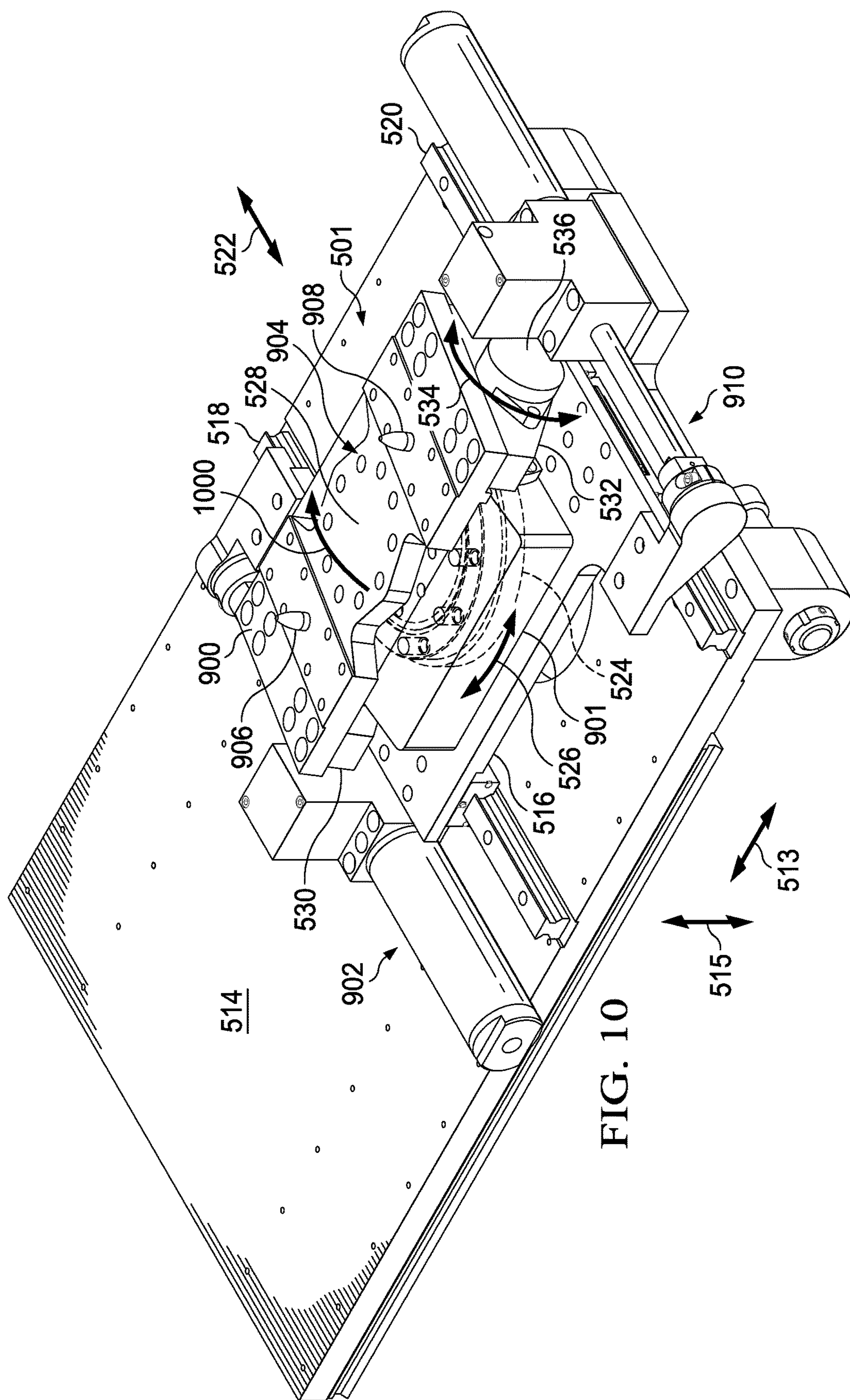
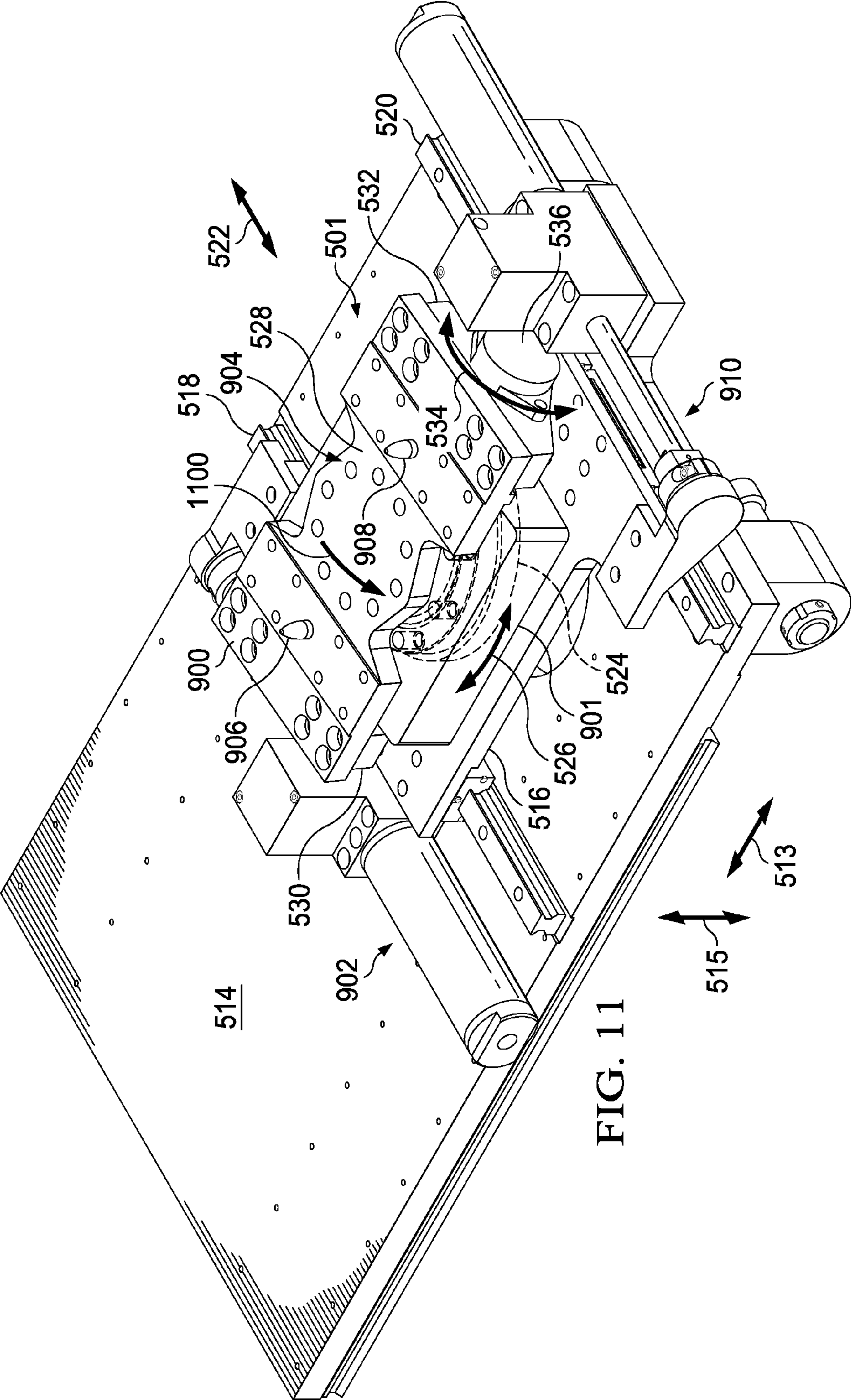
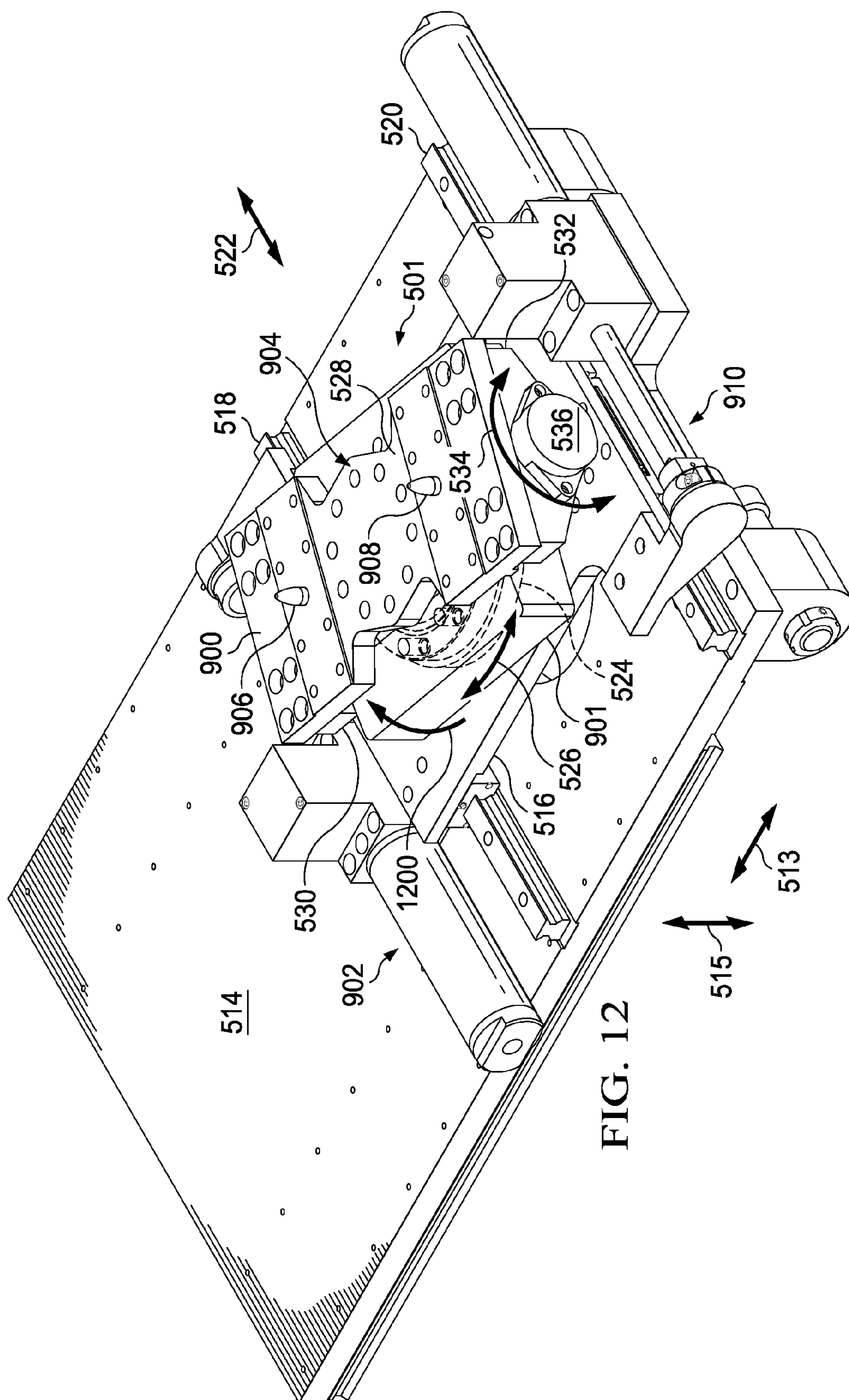


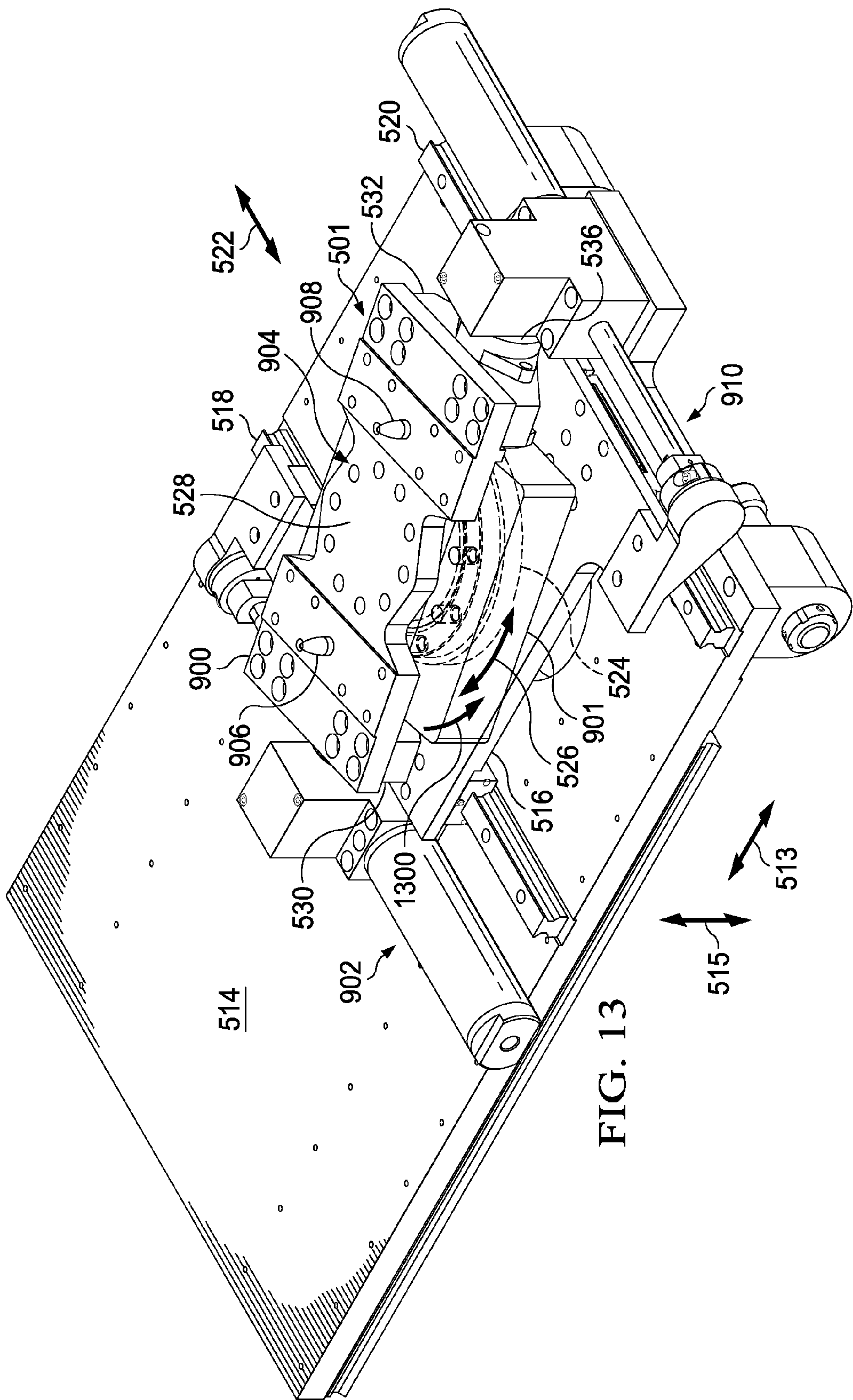
FIG. 8

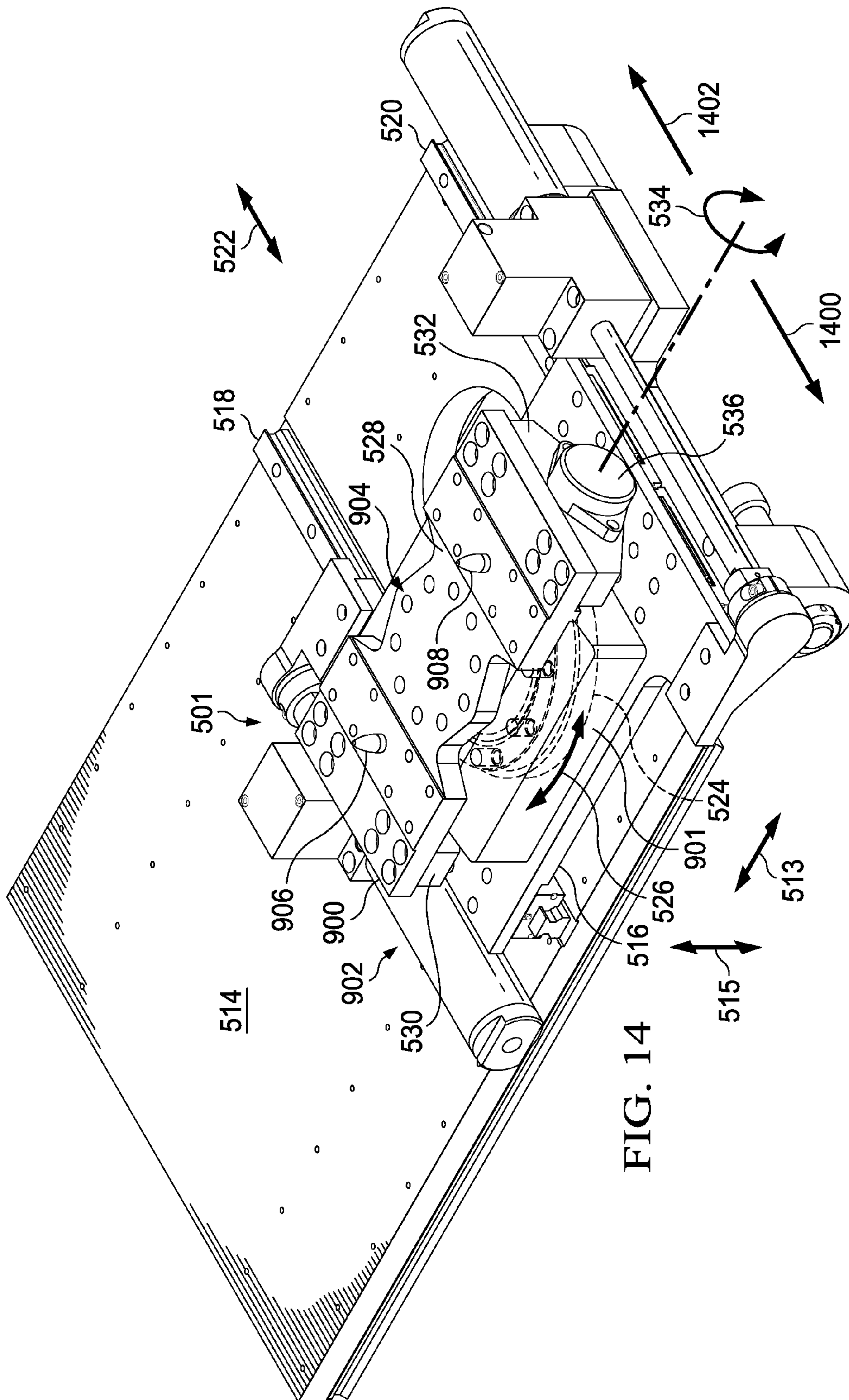


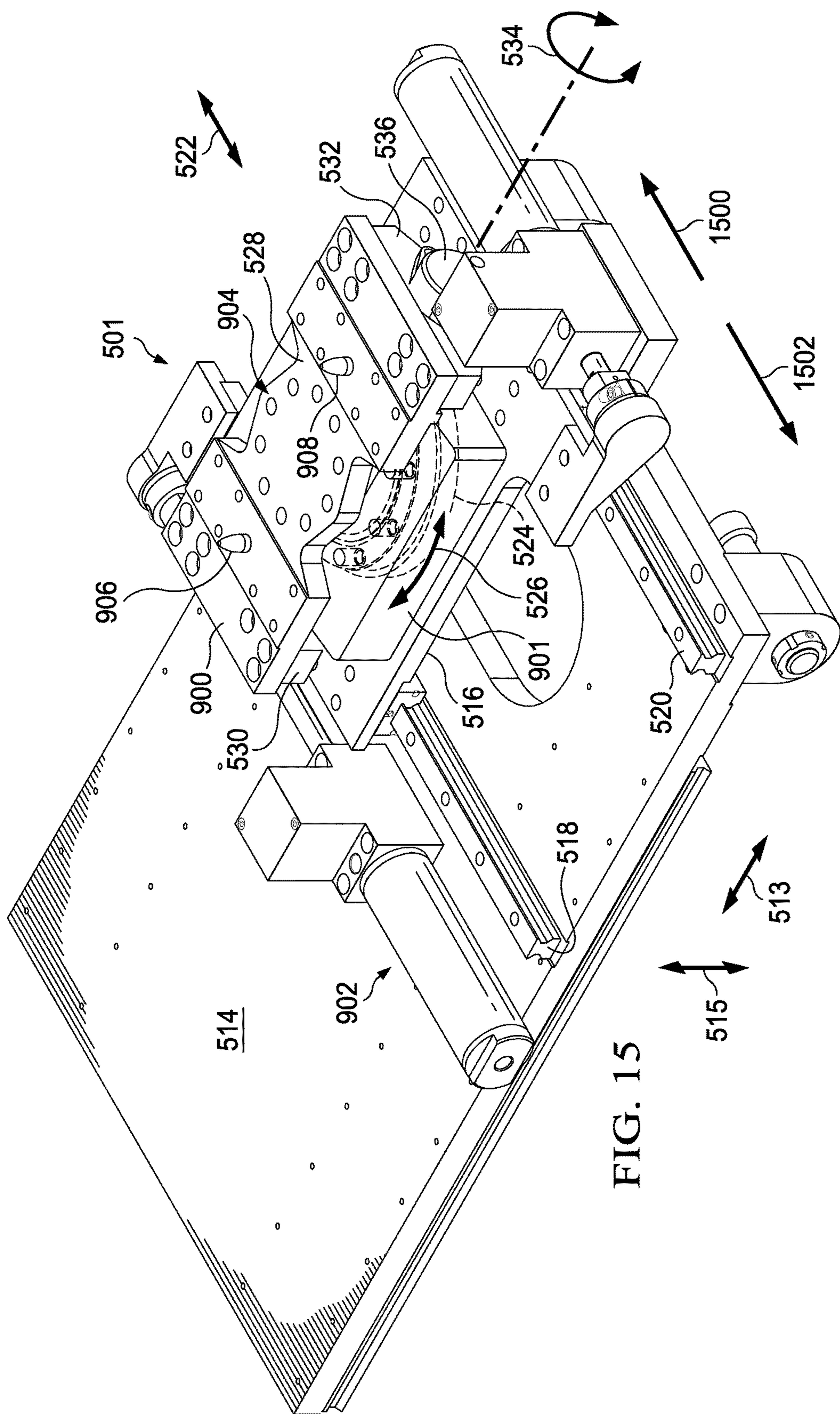












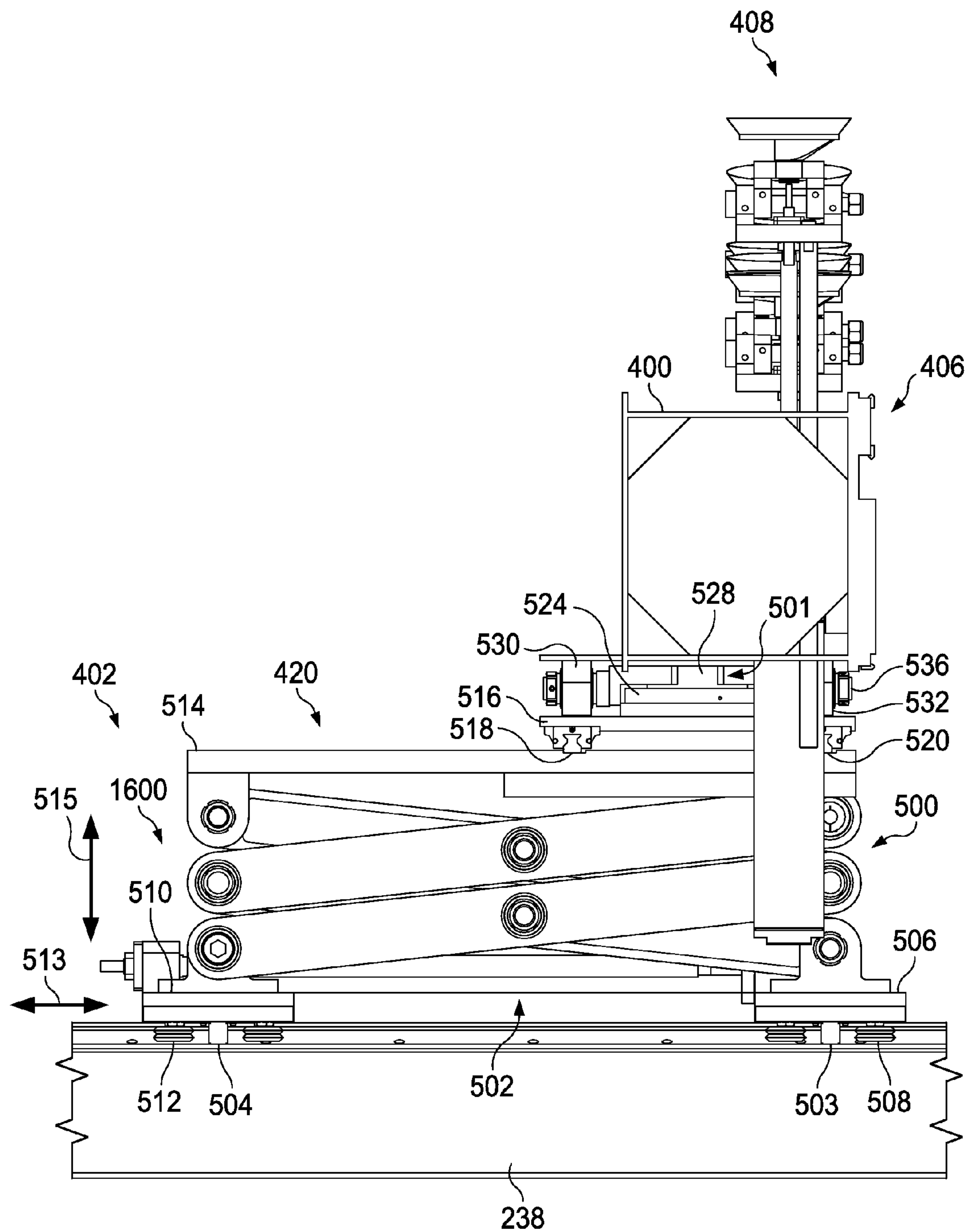


FIG. 16

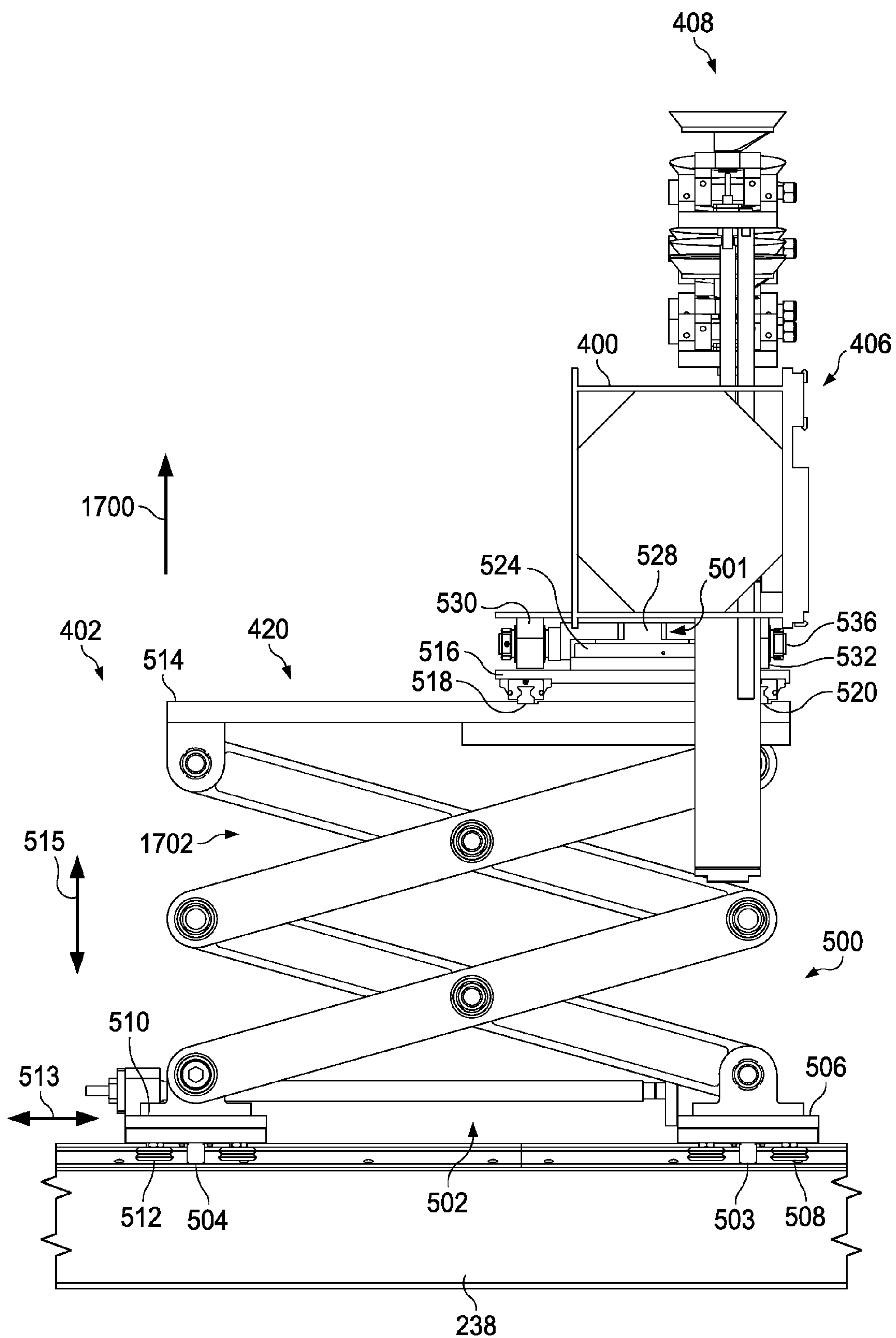


FIG. 17

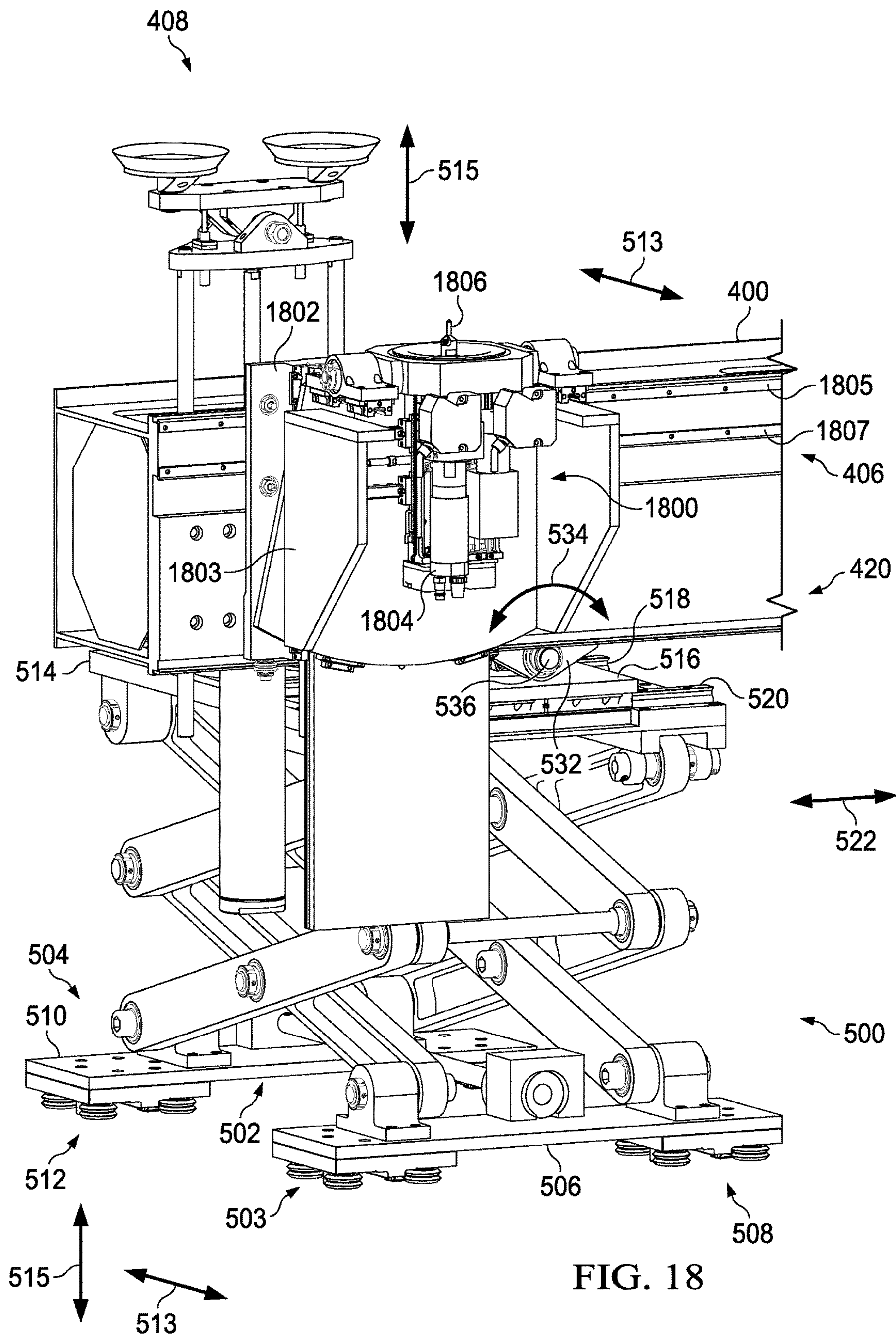
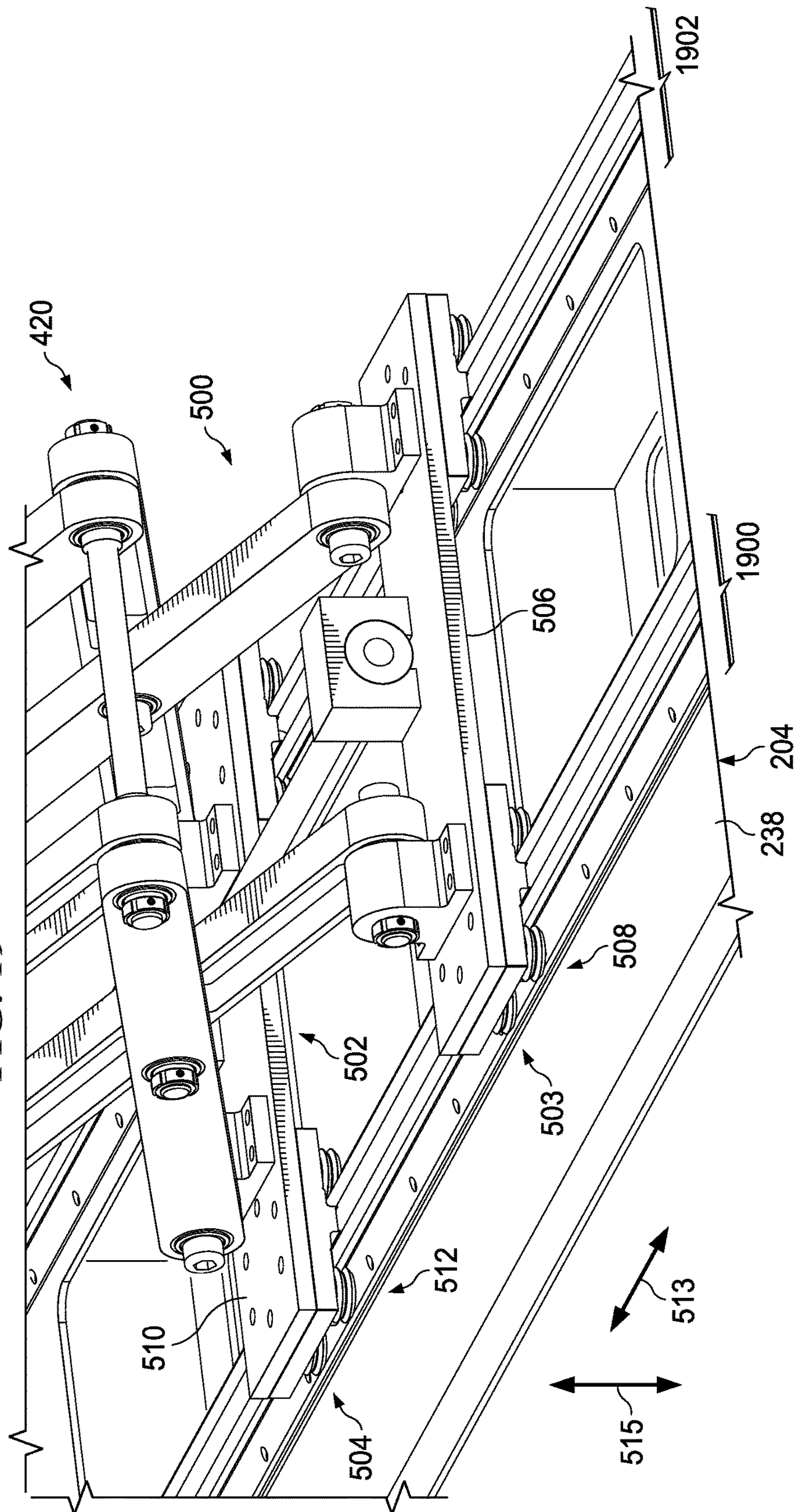


FIG. 19



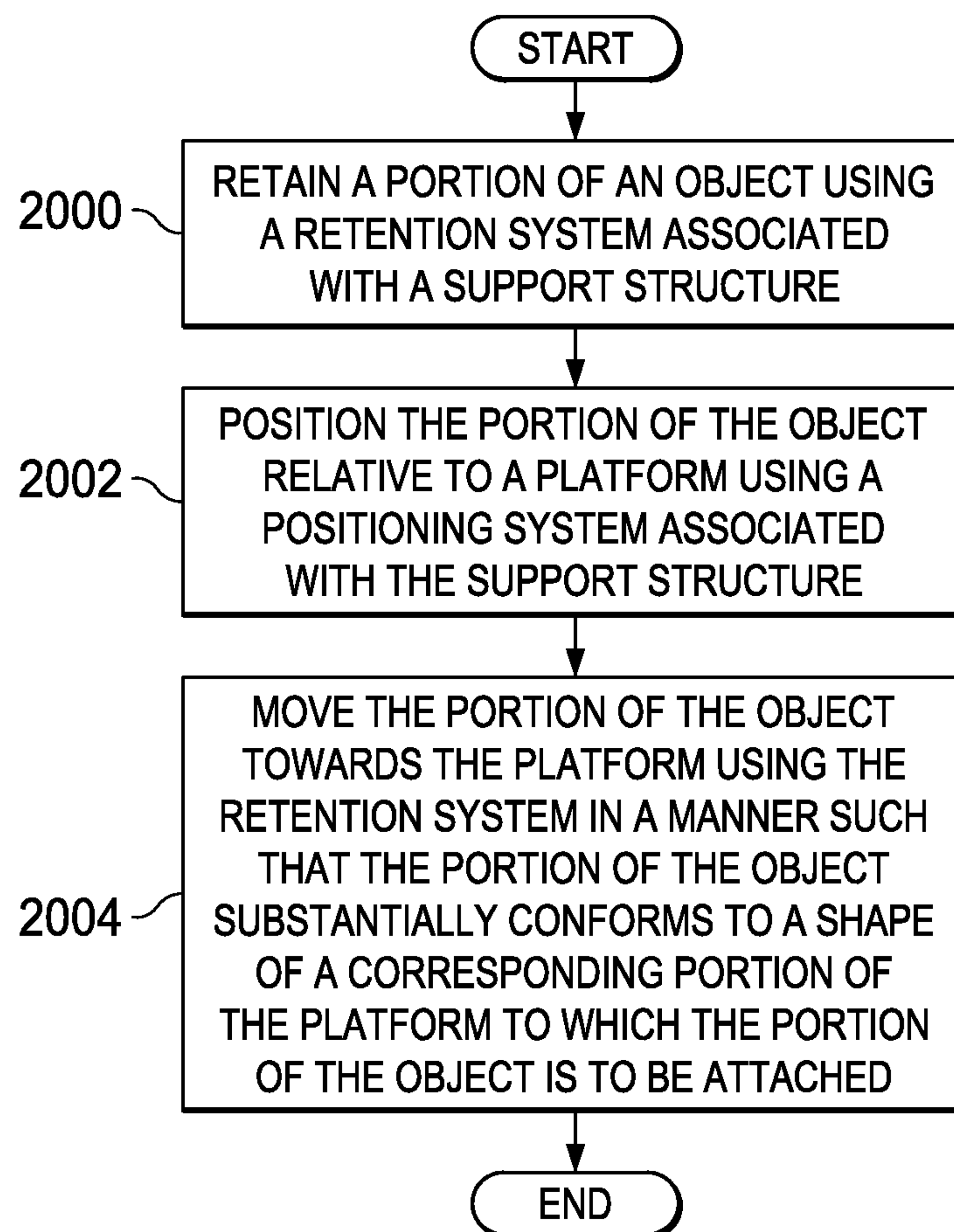


FIG. 20

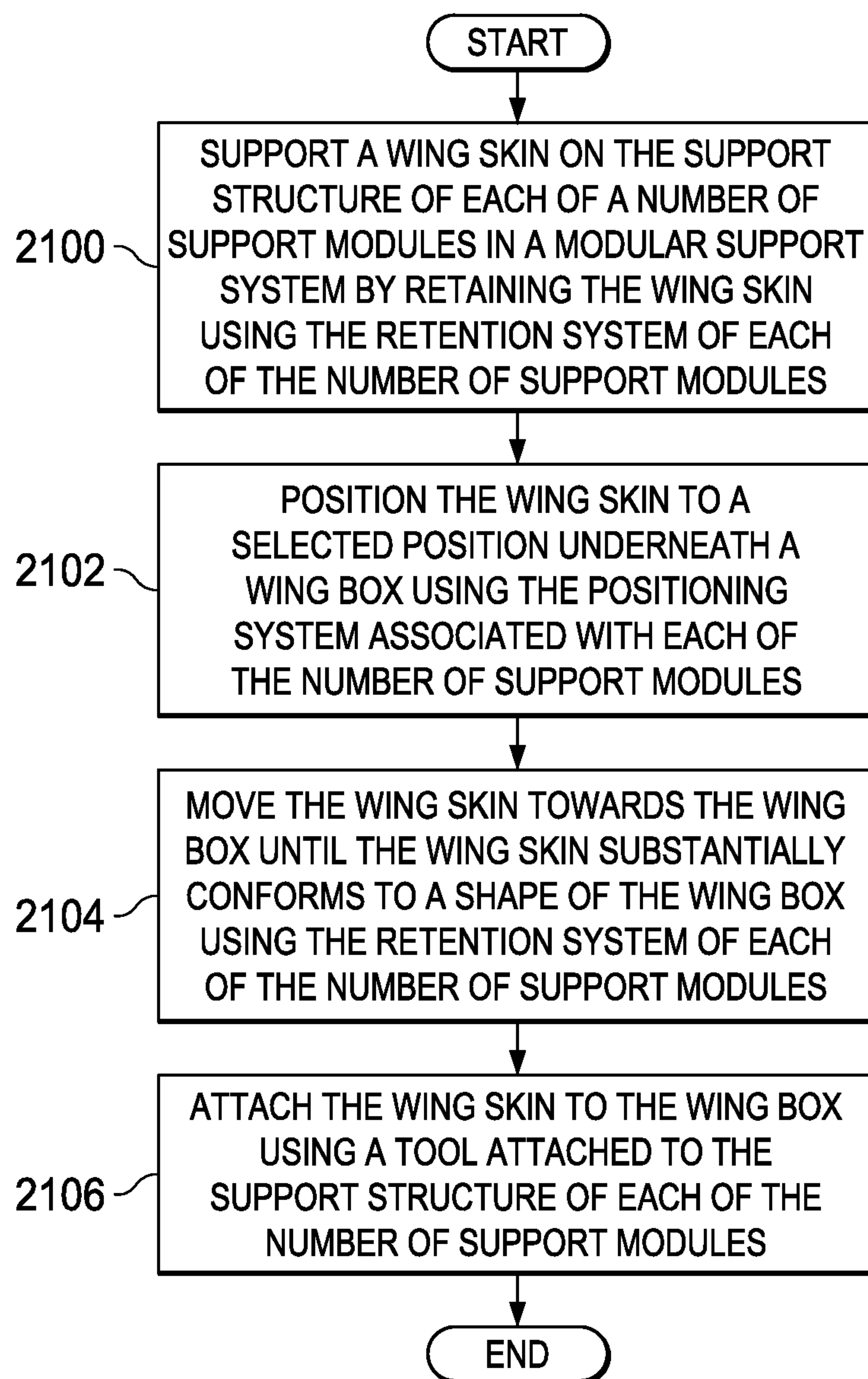


FIG. 21

FIG. 22

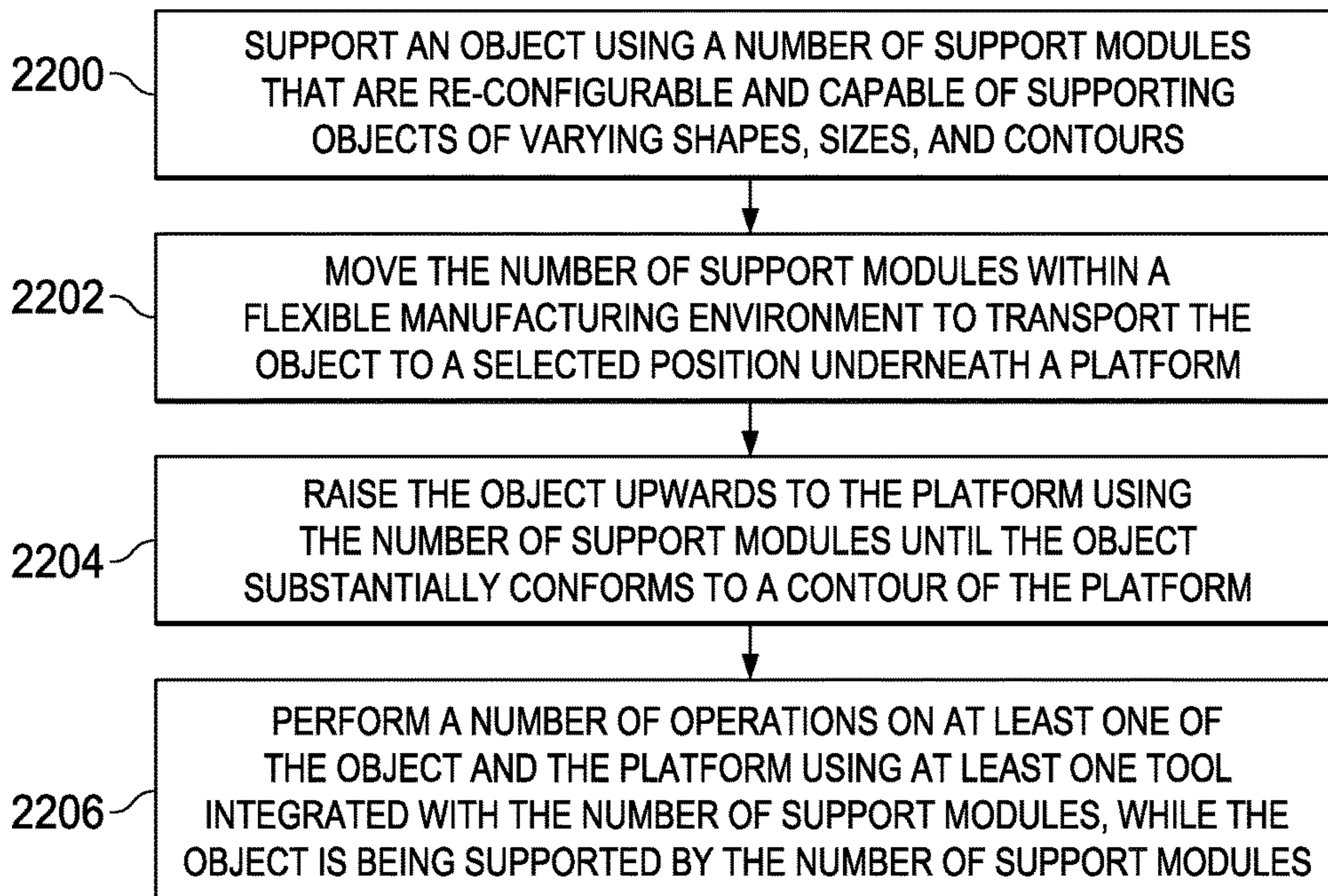
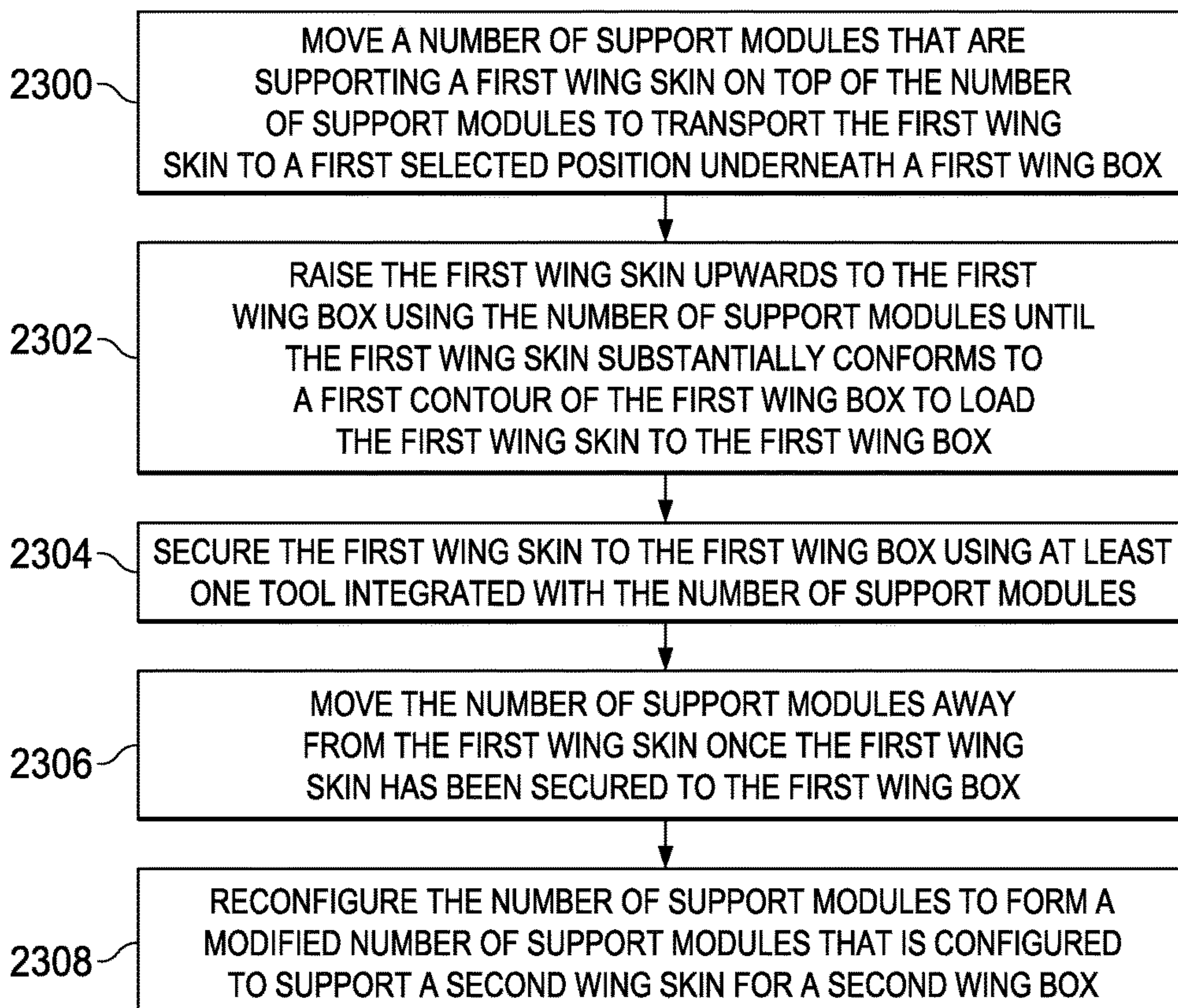
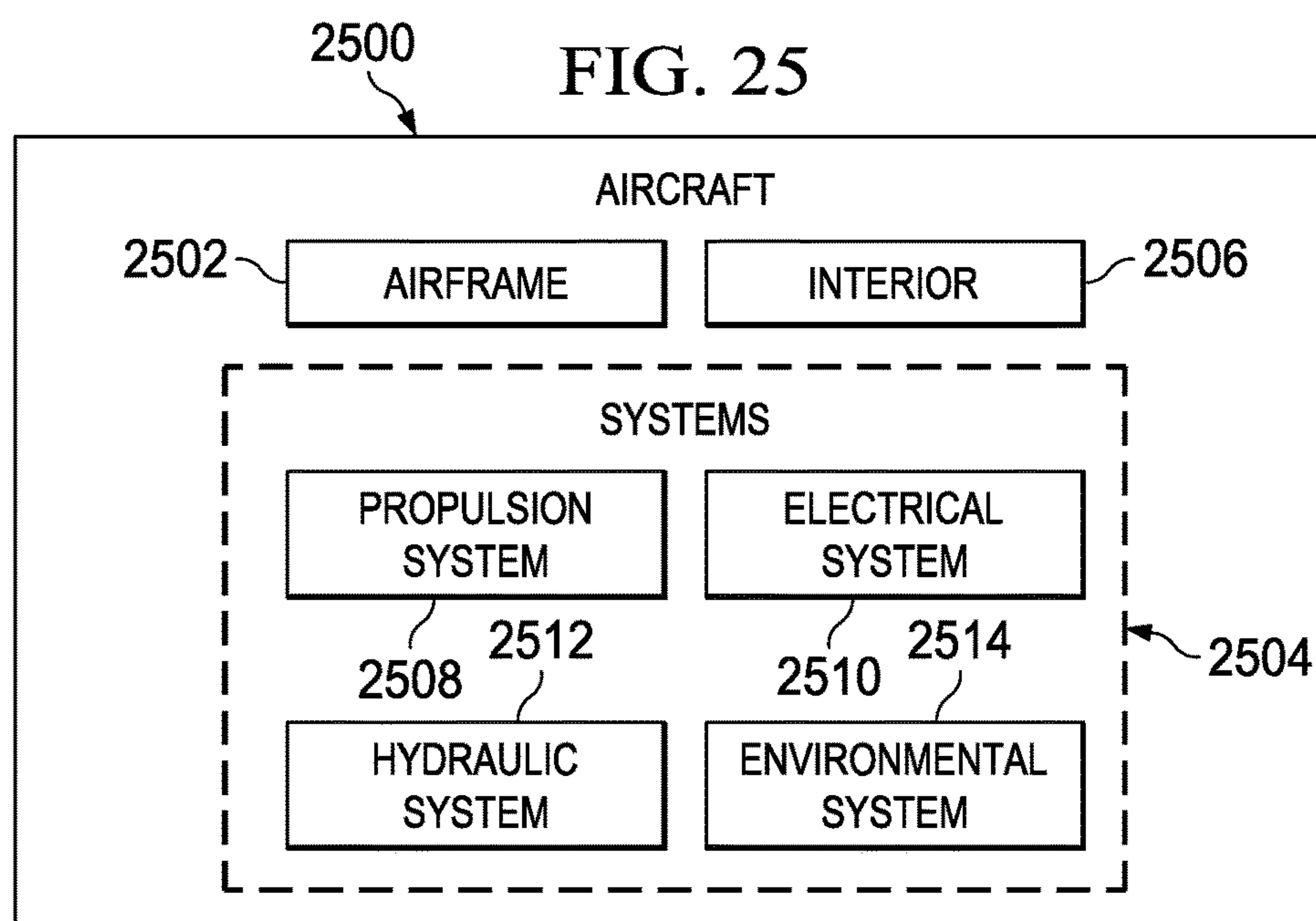
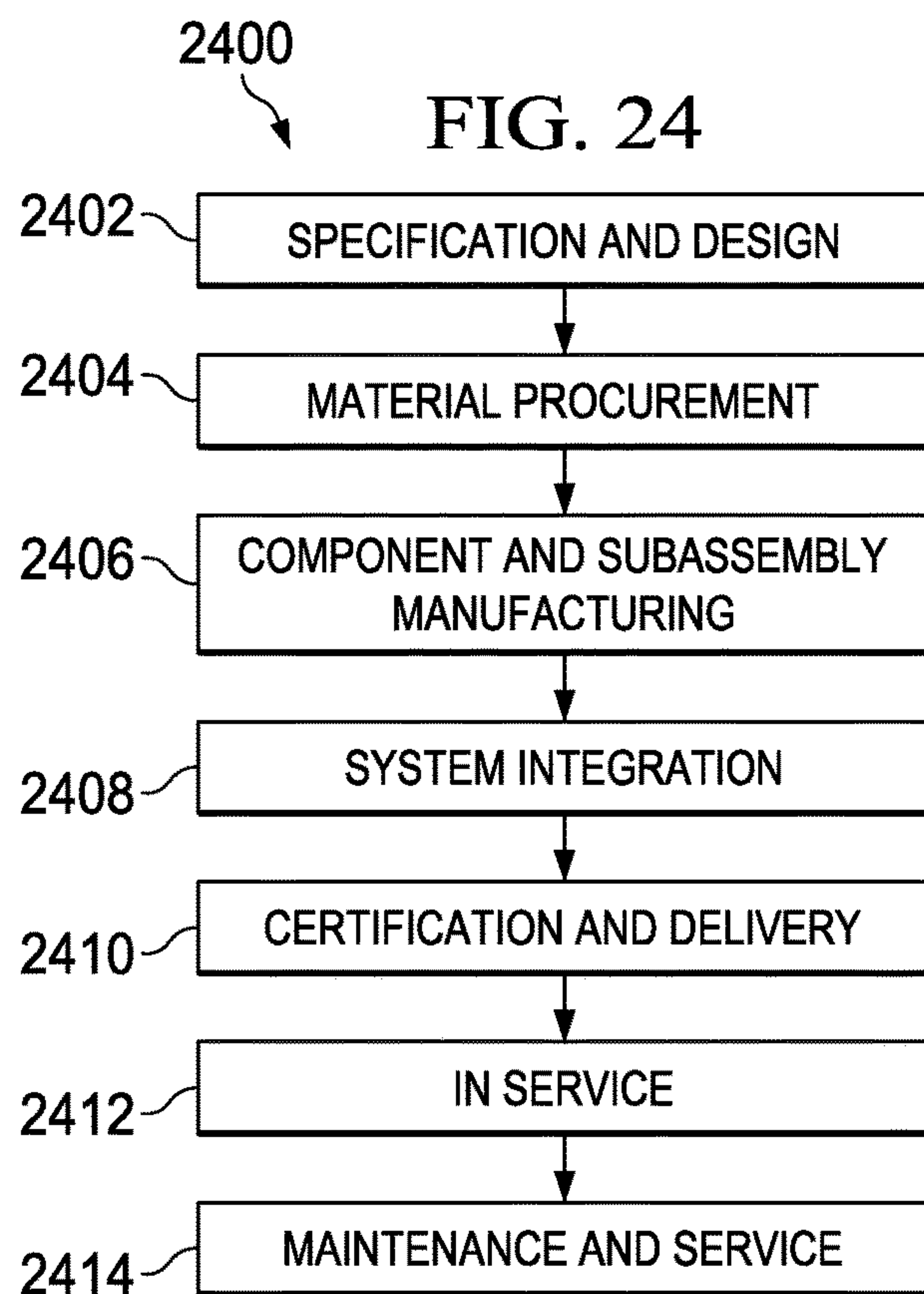


FIG. 23





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**MODULAR AND RECONFIGURABLE
SUPPORT SYSTEM****BACKGROUND INFORMATION**

1. Field

The present disclosure relates generally to installing panels on structures and, in particular, to attaching a wing skin to a wing box. Still more particularly, the present disclosure relates to a modular and reconfigurable support system for use in supporting, positioning, and loading a wing skin underneath a wing box for attachment to the wing box.

2. Background

The wing of an aircraft may be formed using a wing box and two wing skins. One wing skin may be attached to the upper side of the wing box, while the other wing skin may be attached to the lower side of the wing box. Depending on the implementation, a wing skin may be attached to a support structure of the wing box, ribs, spars, stringers, and/or one or more other types of components used to form a wing. Some currently available systems for supporting and loading a wing skin to the lower side of a wing box may create obstacles that limit access to the wing skin and/or wing box by personnel and/or equipment. For example, without limitation, the obstacles presented by this type of support system may present challenges for an operator to access certain portions of the wing skin and/or wing box without running into the support system and/or other equipment.

Further, some currently available systems for supporting and loading a wing skin may be less ergonomic than desired. For example, these currently available systems may require that operators work at a higher work height than desired and/or work from raised platforms. Consequently, performing operations, such as drilling operations, fastening operations, tacking operations, and/or other operations, may be more difficult and/or time-consuming than desired with these types of support systems.

In particular, some currently available systems may require that drilling operations and assembly operations be performed around obstructions created by these support systems. This type of setup may create zones in which personnel may not enter and/or in which work cannot be performed. The system requirements and complexity of the automated tools that may be used with these types of currently available systems may be greater than desired.

Additionally, some currently available support systems may not be reconfigurable. In other words, a support system used for loading wing skins for one type of aircraft may be unable to load wing skins for a different type of aircraft.

Further, these types of support systems may require dedicated tooling, which may increase the cost of using these types of support systems more than desired. The dedicated tooling may be configured for specific types of aircraft, geometry, and/or other factors. Altering a support system to accommodate different types of aircraft and/or different types of geometry may be more difficult than desired and, in some cases, not possible.

Additionally, some support systems may not integrate lifting the wing skins with the handling of the wing systems. For example, in some cases, a dedicated numerically-controlled (NC) lift system may be needed to elevate the tooling needed to assemble a wing skin to a wing box up to the wing box. Using this type of numerically-controlled lift system may be more expensive than desired and may obstruct access to portions of the wing skin and/or the wing box more than desired. Therefore, it would be desirable to have a

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method and apparatus that take into account at least some of the issues discussed above, as well as other possible issues.

SUMMARY

In one illustrative embodiment, an apparatus may comprise a support structure, a positioning system, and a retention system. The positioning system may be associated with the support structure and configured to position the support structure with respect to a number of linear axes. The retention system may be associated with the support structure. The retention system may be configured to retain a portion of an object and move the portion of the object towards a platform such that the portion of the object substantially conforms to a shape of the platform.

In another illustrative embodiment, a modular support system may comprise a number of support modules and a base. A support module in the number of support modules may comprise a support structure, a positioning system, a retention system, and an attachment system. The positioning system may be associated with the support structure and configured to position the support structure with respect to a number of linear axes. The retention system may be associated with the support structure. The retention system may be configured to retain a portion of an object and move the portion of the object towards a platform such that the portion of the object substantially conforms to a shape of the platform. The attachment system may be configured for use in attaching a tool to the support structure. The number of support modules may be configured to move along the base.

In yet another illustrative embodiment, a method for supporting an object may be provided. A portion of the object may be retained using a retention system associated with a support structure. The support structure may be positioned with respect to a number of linear axes such that the portion of the object is positioned relative to a platform. The object may be moved towards the platform using the retention system such that the portion of the object substantially conforms to a shape of the platform.

In still yet another illustrative embodiment, a method for supporting and loading a wing skin underneath a wing box may be provided. The wing skin may be supported on a support structure of each of a number of support modules in a modular support system by retaining the wing skin using a retention system of each of the number of support modules. The wing skin may be positioned in a selected position underneath the wing box using a positioning system of each of the number of support modules. The wing skin may be moved towards the wing box until the wing skin substantially conforms to a shape of the wing box using the retention system of each of the number of support modules. The wing skin may be attached to the wing box using a tool attached to the support structure of each of the number of support modules.

In another illustrative embodiment, a method for transporting and loading an object to a platform in a flexible manufacturing environment may be provided. The object may be supported using a number of support modules that are reconfigurable and capable of supporting objects of varying shapes, sizes, and contours. The number of support modules may be moved within the flexible manufacturing environment to transport the object to a selected position underneath the platform. The object may be raised upwards to the platform using the number of support modules until the object substantially conforms to a contour of the platform. A number of operations may be performed on at least one of the object and the platform using at least one tool

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integrated with the number of support modules, while the object is being supported by the number of support modules.

In yet another illustrative embodiment, a method for transporting and loading wing skins to wing boxes may be provided. A number of support modules supporting a first wing skin on top of the number of support modules may be moved to transport the first wing skin to a first selected position underneath a first wing box. The number of support modules may be part of a modular support system that is reconfigurable. The first wing skin may be raised upwards to the first wing box using the number of support modules until the first wing skin substantially conforms to a first contour of the first wing box to load the first wing skin to the first wing box. The first wing skin may be secured to the first wing box using at least one tool integrated with the number of support modules. The number of support modules may be moved away from the first wing skin once the first wing skin has been secured to the first wing box. The number of support modules may be reconfigured to form a modified number of support modules that is configured to support a second wing skin for a second wing box.

The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is an illustration of a manufacturing environment in the form of a block diagram in accordance with an illustrative embodiment;

FIG. 2 is an illustration of an isometric view of a modular support system in accordance with an illustrative embodiment;

FIG. 3 is an illustration of a wing skin being supported by a modular support system in accordance with an illustrative embodiment;

FIG. 4 is an illustration of an isometric view of a support module in accordance with an illustrative embodiment;

FIG. 5 is an illustration of a positioning assembly in accordance with an illustrative embodiment;

FIG. 6 is an illustration of an isometric view of an adhesion system in accordance with an illustrative embodiment;

FIG. 7 is an illustration of a portion of an adhesion system in accordance with an illustrative embodiment;

FIG. 8 is an illustration of a tilting plate of an adhesion system being tilted in accordance with an illustrative embodiment;

FIG. 9 is an illustration of a portion of a positioning assembly in accordance with an illustrative embodiment;

FIG. 10 is an illustration of an attachment plate being tilted in accordance with an illustrative embodiment;

FIG. 11 is an illustration of an attachment plate being tilted in accordance with an illustrative embodiment;

FIG. 12 is an illustration of an attachment plate being rotated in accordance with an illustrative embodiment;

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FIG. 13 is an illustration of an attachment plate being rotated in accordance with an illustrative embodiment;

FIG. 14 is an illustration of a sliding platform being moved in accordance with an illustrative embodiment;

FIG. 15 is an illustration of a sliding platform being moved in accordance with an illustrative embodiment;

FIG. 16 is an illustration of a side view of a support module in accordance with an illustrative embodiment;

FIG. 17 is an illustration of a side view of a support module in accordance with an illustrative embodiment;

FIG. 18 is an illustration of an automated tool attached to a support module in accordance with an illustrative embodiment;

FIG. 19 is an illustration of an enlarged view of two moveable bases associated with a base in accordance with an illustrative embodiment;

FIG. 20 is an illustration of a process for supporting an object in the form of a flowchart in accordance with an illustrative embodiment;

FIG. 21 is an illustration of a process for supporting and loading a wing skin underneath a wing box in the form of a flowchart in accordance with an illustrative embodiment;

FIG. 22 is an illustration of a process for transporting and loading an object to a platform in a flexible manufacturing environment in the form of a flowchart in accordance with an illustrative embodiment;

FIG. 23 is an illustration of a process for transporting and loading wing skins to wing boxes in the form of a flowchart in accordance with an illustrative embodiment;

FIG. 24 is an illustration of an aircraft manufacturing and service method in the form of a flowchart in accordance with an illustrative embodiment; and

FIG. 25 is an illustration of an aircraft in the form of a block diagram in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

The illustrative embodiments recognize and take into account different considerations. For example, the illustrative embodiments recognize and take into account that it may be desirable to have a reconfigurable support system capable of supporting and loading a wing skin underneath a wing box for an aircraft. Further, the illustrative embodiments recognize and take into account that it may be desirable to have a support system that does not create obstacles for personnel and/or equipment attempting to perform operations on the wing skin and/or the wing box.

Thus, the illustrative embodiments provide an apparatus, system, and method for supporting and loading a wing skin underneath a wing box. In particular, the illustrative embodiments provide a modular support system that may be reconfigured for different types of aircraft. Further, this modular support system may allow for operations to be performed without creating obstacles for the personnel and/or equipment needed to perform these operations. Still further, the modular support system may be configured to hold and support tools, including automated tools, for performing automated operations.

Referring now to the figures and, in particular, with reference to FIG. 1, an illustration of a manufacturing environment is depicted in the form of a block diagram in accordance with an illustrative embodiment. Manufacturing environment 100 is depicted in FIG. 1. In one illustrative example, manufacturing environment 100 may take the form of flexible manufacturing environment 101.

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Within manufacturing environment 100, modular support system 102 may be used to support, transport, and load object 104 into selected position 106 relative to platform 108. In some cases, selected position 106 may be the position at which object 104 needs to be positioned such that object 104 may be attached to platform 108. In this illustrative example, selected position 106 may be a position underneath platform 108. In another illustrative example, selected position 106 may be a position to the side of platform 108.

Object 104 and platform 108 may take a number of different forms. For example, object 104 may take the form of panel 110 and platform 108 may take the form of frame 111. Panel 110 may be any type of panel, may have any of a number of different types of shapes, and/or may be comprised of any number of individual panels that have been connected together. Frame 111 may be any type of frame. In one illustrative example, panel 110 and frame 111 may take the form of wing skin 112 and wing box 113, respectively.

Although modular support system 102 is described as being used with wing skin 112 and wing box 113, modular support system 102 may be configured for use with wing skins and wing boxes of different shapes and/or sizes. In particular, modular support system 102 may be configured to support, transport, and load wing skins of varying contours to wing boxes of different contours. In this manner, modular support system 102 may be considered a flexible modular support system.

Of course, in other illustrative examples, platform 108 may take some other form. Platform 108 may take the form of, for example, without limitation, an aircraft fuselage frame, a ship frame, a building frame, a manmade structure, a bridge, or some other type of platform. Further, object 104 may take some other form such as, for example, without limitation, a window, a door, a flooring, or some other type of object.

As depicted, modular support system 102 may include number of support modules 114 and base 116. As used herein, a “number of” items may include one or more items. In this manner, number of support modules 114 may be one or more support modules. Number of support modules 114 may be supported by base 116 and in some cases, be configured to move along base 116.

Support module 118 may be an example of one implementation for a support module in number of support modules 114. In one illustrative example, when object 104 is being supported by modular support system 102, support module 118 may be used to support portion 120 of object 104. Portion 120 may be a designated portion of object 104. Depending on the implementation, portion 120 of object 104 may be some or all of object 104. As depicted, support module 118 includes support structure 122, positioning system 124, and retention system 126.

Support structure 122 may provide the structural support and load support for portion 120 of object 104. In some cases, support structure 122 may be referred to as a header or a header board. Both positioning system 124 and retention system 126 may be associated with support structure 122. As used herein, when one component is “associated” with another component, the association is a physical association in the depicted examples.

For example, a first component, such as retention system 126, may be considered to be associated with a second component, such as support structure 122, by being secured to the second component, bonded to the second component, mounted to the second component, welded to the second

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component, fastened to the second component, and/or connected to the second component in some other suitable manner. The first component also may be connected to the second component using a third component. Further, the first component may be considered to be associated with the second component by being formed as part of and/or as an extension of the second component.

Additionally, the association between these two components may be a permanent association or a temporary association, depending on the implementation. For example, without limitation, two components that have been connected together may be permanently affixed to each other or may be detachable.

In this illustrative example, retention system 126 may be attached to support structure 122 independently of positioning system 124. Retention system 126 may be used to hold portion 120 of object 104. In one illustrative example, retention system 126 may take the form of number of adhesion systems 128. Each of number of adhesion systems 128 may be used to attach support structure 122 to portion 120 of object 104. More specifically, each of number of adhesion systems 128 may adhere to portion 120 of object 104, which may, in turn, connect support structure 122 to portion 120 of object 104 because support structure 122 is associated with number of adhesion systems 128.

Each of number of adhesion systems 128 may be implemented in a number of different ways. Adhesion system 130 may be an example of one of number of adhesion systems 128. Adhesion system 130 may be implemented using, for example, without limitation, suction cup system 132. Suction cup system 132 may use one or more suction cups to adhere to portion 120 of object 104 by applying at least one of a vacuum and negative pressure to portion 120 of object 104.

As used herein, the phrase “at least one of,” when used with a list of items, means different combinations of one or more of the listed items may be used and only one of the items in the list may be needed. The item may be a particular object, thing, or category. In other words, “at least one of” means any combination of items or number of items may be used from the list, but not all of the items in the list may be required.

For example, “at least one of item A, item B, and item C” may mean item A; item A and item B; item B; item A, item B, and item C; or item B and item C. In some cases, “at least one of item A, item B, and item C” may mean, for example, without limitation, two of item A, one of item B, and ten of item C; four of item B and seven of item C; or some other suitable combination.

Additionally, suction cup system 132 may be configured to move portion 120 of object 104 towards platform 108 and self-adjust as object 104 is attached to platform 108. For example, without limitation, object 104 may have a flat shape, while platform 108 may have a curved shape. Suction cup system 132 may be used to move portion 120 of object 104 towards platform 108. As object 104 encounters platform 108, suction cup system 132 may apply force to object 104 to cause object 104 to substantially conform to the curved portion of platform 108 in contact with object 104. Further, the one or more suction cups within suction cup system 132 may be configured to self-adjust with respect to orientation to allow object 104 to substantially conform to the curved portion of platform 108.

The curved portion of platform 108 may have varying radii of curvature along the curved portion. In some cases, the curved portion may be a concave shape, a convex shape, or some other type of shape. Of course, in other illustrative

examples, platform **108** may have some shape other than a curved shape. For example, without limitation, platform **108** may have a substantially planar shape.

In this illustrative example, positioning system **124** may be used to move support structure **122**. In particular, positioning system **124** may be used to position support structure **122** with respect to number of linear axes **134**. Number of linear axes **134** may include at least one of an X-axis, a Y-axis, and a Z-axis along which support structure **122** may be moved. In this illustrative example, the X-axis may be a longitudinal axis, the Y-axis may be a transverse axis, and the Z-axis may be a vertical axis.

Further positioning system **124** may be used to position support structure **122** with respect to number of rotational axes **136**. Number of rotational axes **136** may include at least one of an A-axis, a B-axis, and a C-axis. As used herein, the A-axis may be a rotational axis describing movement about the X-axis. Further, the B-axis, as used herein, may be a rotational axis describing movement about the Y-axis, and the C-axis, as used herein, may be a rotational axis describing movement about the Z-axis.

Positioning system **124** may be implemented in a number of different ways. For example, without limitation, positioning system **124** may include number of positioning assemblies **138**. In one illustrative example, number of positioning assemblies **138** may be two positioning assemblies. Positioning assembly **140** may be an example of one implementation for a positioning assembly in number of positioning assemblies **138**. Positioning assembly **140** may be configured for association with portion **141** of support structure **122**.

As depicted, positioning assembly **140** may include linear system **142** and rotational system **144**. Linear system **142** may allow portion **141** of support structure **122** to be moved along number of linear axes **134**. Rotational system **144** may allow portion **141** of support structure **122** to be moved along number of rotational axes **136**.

In this illustrative example, linear system **142** and rotational system **144** may be comprised of any number of components and/or devices. For example, without limitation, linear system **142** may include at least one of a lift device, a scissor lift, a plurality of wheels, a plurality of tracks, a plurality of rollers, a plurality of actuation devices, a plurality of slides, or some other type of device. Similarly, rotational system **144** may include, for example, without limitation, at least one of a plurality of bearings, a number of plates, a number of tilting devices, a number of rotating devices, a number of actuators, a number of feedback encoders, a number of drive motors, a number of brakes, or some other type of device.

Positioning system **124** may be used to both hold and position support structure **122** relative to base **116**. Further, positioning system **124** may be used to position support structure **122** such that portion **120** of object **104** attached to support structure **122** through retention system **126** may also be positioned.

In some illustrative examples, attachment system **146** may be associated with support structure **122**. Attachment system **146** may be considered part of or separate from support module **118**, depending on the implementation. Further, attachment system **146** may be considered part of or separate from modular support system **102**, depending on the implementation.

Attachment system **146** may be used to attach tool **148** to support structure **122**. Attachment system **146** may comprise, for example, without limitation, a number of rails that may be used to hold tool **148** and allow tool **148** to move

along support structure **122**. Tool **148** may be used to perform number of operations **152** on object **104** and/or platform **108**. Number of operations **152** may include, for example, without limitation, at least one of drilling, tacking, fastening, riveting, countersinking, nut-driving, painting, reworking, tagging, marking, inspecting, imaging, videoing, or some other type of operation.

Tool **148** may include any number of tools, devices, pieces of equipment, and/or other elements needed to perform number of operations **152**. In some illustrative examples, tool **148** may take the form of automated tool **150**. Automated tool **150** may be any tool that may be operated independently of a human operator or at least partially independently of a human operator. In some cases, automated tool **150** may be a semi-automated tool.

Positioning system **124**, retention system **126**, and number of adhesion systems **128** in support module **118** may be configured such that support module **118** may be configured to support different portions of an object when needed. In other words, support module **118** may be reconfigurable such that some other portion of object **104**, other than portion **120**, may be supported by support module **118**. Further, support module **118** may be reconfigurable such that a portion of an object having a different size, shape, and/or contour as compared to object **104** may be supported by support module **118**. For example, without limitation, number of support modules **114** may be reconfigured to support a new object to be loaded to a new platform in which the new object has a different contour compared to object **104**. In this manner, support module **118** may be flexible.

For example, without limitation, control system **154** may be used to control modular support system **102**. Control system **154** may be implemented using hardware, software, or a combination of the two. In one illustrative example, control system **154** may be implemented using a computer system comprising one or more computers. When more than one computer is present, these computers may be in association with each other.

Depending on the implementation, control system **154** may be used to control at least one of positioning system **124**, retention system **126**, attachment system **146**, or automated tool **150**. In this manner, control system **154** may be used to position object **104** relative to platform **108** such that object **104** may be fastened to platform **108** according to specified requirements, tolerances, and/or rules.

Modular support system **102** may be both modular and reconfigurable. In particular, the particular types of support modules used in number of support modules **114** may be changed at any point in time. For example, in some cases, number of support modules **114** may include ten support modules all having support structures of the same length. However, in another illustrative example, each support module in number of support modules **114** may have a support structure with a different length than the other support structures.

Further, support modules may be switched out, replaced, and/or altered at any point in time such that modular support system **102** may be configured for use with different types of objects for different types of platforms. In particular, number of support modules **114** may be reconfigured by at least one of changing a position of a support module in number of support modules **114** relative to other support modules in number of support modules **114**, replacing a support module in number of support modules **114**, altering a support module in number of support modules **114**, removing a support module from number of support modules **114**, or adding a new support module to number of support modules

114. In this manner, modular support system 102 may be reconfigured for each different type of object to be supported by modular support system 102.

Typically, the ground in flexible manufacturing environment 101 may be substantially smooth. The type of modular support system 102 described above may be suitable for use on a floor that is substantially smooth, such as, for example, without limitation, a concrete floor. Modular support system 102 may be used as part of a flexible manufacturing system in flexible manufacturing environment 101.

Further, the modular nature of modular support system 102 may enable progressive removal of number of support modules 114 as object 104 supported by modular support system 102 is loaded to and secured to platform 108. In other words, number of support modules 114 may be moved away from object 104 in a progressive manner once object 104 is secured to platform 108. In particular, a support module in number of support modules 114 may be moved away from object 104 when the portion of object 104 being supported by the support module has been secured to platform 108. For example, without limitation, when portion 120 of object 104 being supported by support module 118 has been secured to platform 108, support module 118 may be removed from underneath platform 108.

The illustration of manufacturing environment 100 and modular support system 102 in FIG. 1 is not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be optional. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

For example, without limitation, attachment system 146 may not be associated with support structure 122. In other illustrative examples, adhesion system 130 may be implemented using some other type of adhesion system other than suction cup system 132. For example, adhesion system 130 may be implemented with pads that use friction to prevent sliding.

In still other illustrative examples, retention system 126 may be implemented using a number of mechanical attachment devices instead of number of adhesion systems 128. In one illustrative example, retention system 126 may be implemented using a number of inflatable bladders and a roughly shaped contour board to support and retain object 104.

With reference now to FIG. 2, an illustration of an isometric view of a modular support system is depicted in accordance with an illustrative embodiment. In this illustrative example, modular support system 200 is an example of one implementation for modular support system 102 in FIG. 1.

As depicted, modular support system 102 may include number of support modules 202 and base 204. Number of support modules 202 and base 204 may be examples of implementations for number of support modules 114 and base 116, respectively, in FIG. 1.

In this illustrative example, number of support modules 202 includes support modules 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, and 226. Each of these support modules may be an example of an implementation for support module 118 in FIG. 1.

Further, base 204 may be comprised of first track system 228, second track system 230, third track system 232, and fourth track system 234. First track system 228 may include

track 236 and track 238. Second track system 230 may include track 240 and track 242. Third track system 232 may include track 244, and fourth track system 234 may include track 246. Number of support modules 202 may be positioned on these different tracks and allowed to move along these tracks.

With reference now to FIG. 3, an illustration of a wing skin being supported by modular support system 200 from FIG. 2 is depicted in accordance with an illustrative embodiment. In this illustrative example, wing skin 300 is being supported by modular support system 200. Wing skin 300 may be an example of one implementation for wing skin 112 in FIG. 1.

With reference now to FIG. 4, an illustration of an isometric view of support module 210 from FIG. 2 is depicted in accordance with an illustrative embodiment. As depicted, support module 210 may include support structure 400, positioning system 402, and retention system 404. Support structure 400, positioning system 402, and retention system 404 may be examples of implementations for support structure 122, positioning system 124, and retention system 126, respectively, in FIG. 1.

Both positioning system 402 and retention system 404 may be associated with support structure 400. Further, attachment system 406 may be associated with support structure 400. Attachment system 406 may be used to hold a tool, such as tool 148 in FIG. 1.

In this illustrative example, retention system 404 may include adhesion systems 408, 410, 412, 414, 416, and 418. These adhesion systems may be an example of one implementation for number of adhesion systems 128 in FIG. 1. Further, each of adhesion systems 408, 410, 412, 414, 416, and 418 may be an example of an implementation for adhesion system 130 in FIG. 1.

Positioning system 402 may include positioning assembly 420 and positioning assembly 422. Positioning assembly 420 and positioning assembly 422 may be examples of one implementation for number of positioning assemblies 138 in FIG. 1. Further, each of positioning assembly 420 and positioning assembly 422 may be an example of an implementation for positioning assembly 140 in FIG. 1.

With reference now to FIG. 5, an illustration of positioning assembly 420 from FIG. 4 is depicted in accordance with an illustrative embodiment. In this illustrative example, positioning assembly 420 may include linear system 500 and rotational system 501. Linear system 500 and rotational system 501 may be examples of implementations for linear system 142 and rotational system 144, respectively, in FIG. 1.

As depicted, linear system 500 may include scissor lift 502, moveable base 503, moveable base 504, actuation system 505, and work platform 514. Moveable base 503 may include base structure 506 and plurality of rollers 508 attached to base structure 506. Moveable base 504 may include base structure 510 and plurality of rollers 512 attached to base structure 510. Plurality of rollers 508 and plurality of rollers 512 may be configured to move positioning assembly 420 along track 238 in FIG. 2 in a direction substantially parallel to X-axis 513.

Scissor lift 502 may be a type of moveable platform that can move vertically. In this illustrative example, scissor lift 502 may use linked, folding structures arranged in a criss-cross pattern to form a scissor mechanism. Vertical motion in a direction substantially parallel to Z-axis 515 may be achieved by the application of pressure to moveable base 503 and moveable base 504.

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Moveable base **503** and moveable base **504** may be moved towards each other or away from each other using actuation system **505**. Moving moveable base **503** and moveable base **504** towards each other may cause the crisscross pattern to be elongated and work platform **514** to be moved upwards vertically. Moving moveable base **503** and moveable base **504** away from each other may cause the crisscross pattern to be contracted and work platform **514** to be moved downwards vertically. In this manner, vertical motion of scissor lift **502** may be achieved. Of course, in other illustrative examples, scissor lift **502** may be operated and actuated in some other manner.

Actuation system **505** may be implemented in a number of different ways. Actuation system **505** may include, for example, without limitation, at least one of a hydraulic actuator, a pneumatic actuator, a mechanical actuation device, an electrical actuation device, or some other type of actuation device.

Linear system **500** may also include sliding platform **516**, rail **518**, and rail **520**. Rail **518** and rail **520** may be attached to work platform **514**. Sliding platform **516** may be configured to slide along rail **518** and rail **520** in either direction along Y-axis **522** in this illustrative example. X-axis **513**, Z-axis **515**, and Y-axis **522** may be examples of axes in number of linear axes **134** in FIG. 1.

Rotational system **501** may be associated with sliding platform **516**. Rotational system **501** may include rotating device **524** configured to rotate along a rotational axis substantially concentric to C-axis **526**. Rotational system **501** may also include attachment plate **528** and a number of tilting elements, which may include tilting element **530** and tilting element **532**. Tilting element **530** and tilting element **532** may be configured to rotate along a rotational axis substantially concentric to A-axis **534** about pivot element **536**.

In this illustrative example, support structure **400** from FIG. 4 may be attached to positioning assembly **420** by attaching to tilting element **530** and tilting element **532**. Tilting element **530** and tilting element **532** may be associated with rotating device **524** through attachment plate **528**. Rotation of rotating device **524** may also cause attachment plate **528**, and thereby tilting element **530** and tilting element **532**, to rotate. However, rotation of tilting element **530** and tilting element **532** may not cause any rotation of rotating device **524**. In this manner, tilting element **530** and tilting element **532** may be configured to move independently of rotating device **524**.

Further, any linear movement by linear system **500** may affect rotational system **501**. However, rotational movement by rotational system **501** may not affect linear system **500**. For example, without limitation, any movement along X-axis **513**, Y-axis **522**, and/or Z-axis **515**, as described above, may cause rotational system **501** to be moved in the same direction. However, any movement along C-axis **526** and/or A-axis **534** may not cause linear system **500** to be moved in any direction. Movement along C-axis **526** or A-axis **534** may be considered rotational movement.

With reference now to FIG. 6, an illustration of an isometric view of adhesion system **410** from FIG. 4 is depicted in accordance with an illustrative embodiment. In this illustrative example, adhesion system **410** may take the form of suction cup system **600**. Suction cup system **600** may be an example of one implementation for suction cup system **132** in FIG. 1.

As depicted, suction cup system **600** may include attachment structure **601** used to attach suction cup system **600** to

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support structure **400** in FIG. 4. In this illustrative example, attachment structure **601** may include element **602** and element **604**.

Further, suction cup system **600** may also include actuation system **606**. Actuation system **606** may be configured to move stabilizing structure **608** in a direction along arrow **610**. Arrow **610** may be substantially parallel to Z-axis **515** seen in FIG. 5. Actuation system **606** may include any number of actuation devices.

Suction cup system **600** may also include elongate member **612** and elongate member **614**. These elongate members may be alignment rods used to ensure that stabilizing structure **608** remains stable during vertical motion in a direction along arrow **610**. Operation of actuation system **606** may cause elongate member **612**, elongate member **614**, and elongate member **615** associated with actuation system **606** to move stabilizing structure **608** upwards or downwards.

As depicted, suction cup **616** and suction cup **618** may be attached to tilting plate **620**. Tilting plate **620** may be associated with stabilizing structure **608**. Tilting plate **620** may be rotated in a direction along arrow **624** about pivot element **622**. Movement along arrow **624** may be rotational movement. In this manner, tilting plate **620** may be tilted. In this illustrative example, arrow **624** may be substantially concentric to A-axis **534** in FIG. 5. When tilting plate **620** is rotated, the orientation of suction cup **616** and suction cup **618** may be changed.

In particular, suction cup **616** and suction cup **618** may have spherical bearing interfaces (not shown in this view) with tilting plate **620**. These spherical bearing interfaces may allow suction cup **616** and suction cup **618** to tilt relative to each other to ensure that suction cup **616** and suction cup **618** remain substantially aligned with wing skin **300** in FIG. 3 even when tilting plate **620** is rotated.

With reference now to FIG. 7, an illustration of a portion of adhesion system **410** from FIG. 4 is depicted in accordance with an illustrative embodiment. In this illustrative example, suction cup **616** and suction cup **618** may be in a centered position. In particular, tilting plate **620** may not be tilted.

In this illustrative example, gas spring **700** and gas spring **702** may be associated with tilting plate **620**. Gas spring **700** and gas spring **702** may be configured to compress in response to pressure or force. For example, without limitation, force may be applied to suction cup **618** in the direction of arrow **704**, which may cause gas spring **702** to compress. When gas spring **702** compresses, tilting plate **620** may rotate about pivot element **622** towards gas spring **702**.

In one illustrative example, actuation system **606** from FIG. 6 may be configured to move suction cup **616** and suction cup **618** upwards until the portion of wing skin **300** from FIG. 3 retained by these suction cups encounters the lower side of a wing box (not shown). In other words, actuation system **606** may be used to apply force to wing skin **300** such that wing skin **300** is moved towards the wing box.

Actuation system **606** from FIG. 6 may continue to move these suction cups upwards until the portion of wing skin **300** retained by the suction cups substantially conforms to the portion of the wing box being encountered. When the lower side of the wing box encountered has a curved shape, the bending or curving of wing skin **300** to conform to the shape of the portion of the wing box may cause at least one of gas spring **700** or gas spring **702** to compress. This compression may allow tilting plate **620** to tilt such that the

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portion of wing skin **300** being retained by suction cup **616** and suction cup **618** may substantially conform to this curved shape.

Turning now to FIG. **8**, an illustration of tilting plate **620** of adhesion system **410** from FIG. **6** being tilted is depicted in accordance with an illustrative embodiment. In this illustrative example, tilting plate **620** has tilted in the direction of arrow **800**. Consequently, the orientation of suction cup **616** and suction cup **618** may be changed.

With reference now to FIG. **9**, an illustration of a portion of positioning assembly **420** from FIG. **5** is depicted in accordance with an illustrative embodiment. In this illustrative example, attachment plate **900**, housing **901**, and centering system **902** may be added to positioning assembly **420**.

Attachment plate **900** may be attached to tilting element **530** or tilting element **532**. Tilting element **530** and tilting element **530** may be attached to housing **901**. Housing **901** may be used to house rotating device **524** (shown in phantom). Attachment plate **900** may have plurality of holes **904**, protruding member **906**, and protruding member **908**. Attachment plate **900** may be configured to allow different types of support structures to be attached to rotational system **501**.

Centering system **902** may be used to center sliding platform **516** along rail **518** and rail **520**. In this illustrative example, sliding platform **516** has been moved to center position **910**. Center position along rail **518** and rail **520** may be a neutral position, or default position, for sliding platform **516**.

Turning now to FIG. **10**, an illustration of attachment plate **900** from FIG. **9** being tilted is depicted in accordance with an illustrative embodiment. In this illustrative example, attachment plate **900** has been tilted in the direction of arrow **1000**. In particular, tilting element **530** and tilting element **532** have rotated about pivot element **536** in the direction of arrow **1000**, which in turn, may cause rotation of attachment plate **900** in the direction of arrow **1000**.

With reference now to FIG. **11**, an illustration of attachment plate **900** from FIG. **9** being tilted is depicted in accordance with an illustrative embodiment. In this illustrative example, attachment plate **900** has been tilted in the direction of arrow **1100**.

With reference now to FIG. **12**, an illustration of attachment plate **900** from FIG. **9** being rotated is depicted in accordance with an illustrative embodiment. In this illustrative example, attachment plate **900** has been rotated in the direction of arrow **1200**. In particular, rotating device **524** and housing **901** have rotated in the direction of arrow **1200**, which in turn, may cause rotation of attachment plate **900** in the direction of arrow **1200**.

With reference now to FIG. **13**, an illustration of attachment plate **900** from FIG. **9** being rotated is depicted in accordance with an illustrative embodiment. In this illustrative example, attachment plate **900** has been rotated in the direction of arrow **1300**.

With reference now to FIG. **14**, an illustration of sliding platform **516** from FIG. **9** being moved is depicted in accordance with an illustrative embodiment. In this illustrative example, sliding platform **514** has been moved in the direction of arrow **1400**. Centering system **902** may be used to move sliding platform **516** in the direction of arrow **1402** back to center position **910** in FIG. **9**.

With reference now to FIG. **15**, an illustration of sliding platform **516** from FIG. **9** being moved is depicted in accordance with an illustrative embodiment. In this illustrative example, sliding platform **514** has been moved in the

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direction of arrow **1500**. Centering system **902** may be used to move sliding platform **516** in the direction of arrow **1502** back to center position **910** in FIG. **9**.

Turning now to FIG. **16**, an illustration of a side view of support module **210** from FIG. **4** is depicted in accordance with an illustrative embodiment. In this illustrative example, scissor lift **502** may be in contracted state **1600**. In contracted state **1600**, the crisscross pattern of scissor lift **502** may be fully contracted.

With reference now to FIG. **17**, an illustration of a side view of support module **210** from FIG. **4** is depicted in accordance with an illustrative embodiment. In this illustrative example, scissor lift **502** has been elongated in the direction of arrow **1700** to move scissor lift **502** into elongated state **1702**. In particular, the crisscross pattern of scissor lift **502** has been elongated to move scissor lift **502** into elongated state **1702**. In elongated state **1702**, work platform **514** may be raised higher than the position of work platform **514** when scissor lift **502** is in contracted state **1600** from FIG. **16**.

With reference now to FIG. **18**, an illustration of an automated tool attached to support module **210** from FIG. **2** is depicted in accordance with an illustrative embodiment. In this illustrative example, automated tool **1800** has been attached to support structure **400** of support module **210** using attachment system **406**. Automated tool **1800** may be an example of one implementation for automated tool **150** in FIG. **1**.

As depicted, automated tool **1800** may include attachment structure **1802**, positioning system **1803**, and drilling device **1804**. Drilling device **1804** may include drill bit **1806** for forming holes.

In this illustrative example, attachment structure **1802** may be used to attach automated tool **1800** to attachment system **406**. In particular, attachment structure **1802** may be used to attach automated tool **1800** to rail **1805** and **1807** of attachment system **406**. In this manner, automated tool **1800** may be allowed to move along rail **1805** and rail **1807** in a direction substantially parallel to Y-axis **522**.

Further, positioning system **1803** may be used to move drilling device **1804** in a direction substantially parallel to X-axis **513** and/or Z-axis **515**. In some cases, positioning system **1803** may be used to rotate drilling device **1804** about any number of rotational axes.

With reference now to FIG. **19**, an illustration of an enlarged view of moveable base **503** and moveable base **504** from FIG. **5** associated with base **204** from FIG. **2** is depicted in accordance with an illustrative embodiment. In this illustrative example, plurality of rollers **508** and plurality of rollers **512** may be retained with first portion **1900** of track **238** and second portion **1902** of track **238**. Plurality of rollers **508** and plurality of rollers **512** may allow positioning assembly **420** to be moved along track **238** in a direction substantially parallel to X-axis **513**.

The illustrations of modular support system **200** in FIGS. **2-3**, support module **210** in FIG. **4** and FIGS. **16-19**, positioning assembly **420** in FIG. **5** and FIGS. **9-15**, adhesion system **410** in FIGS. **6-8**, are not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be optional.

The different components shown in FIGS. **2-19** may be illustrative examples of how components shown in block form in FIG. **1** can be implemented as physical structures. Additionally, some of the components in FIGS. **2-19** may be

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combined with components in FIG. 1, used with components in FIG. 1, or a combination of the two.

With reference now to FIG. 20, an illustration of a process for supporting an object is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in FIG. 20 may be implemented using modular support system 102 in FIG. 1 to support object 104 from FIG. 1. In particular, the process may be implemented using support module 118 in FIG. 1.

In this illustrative example, portion 120 of object 104 may be retained using retention system 126 associated with support structure 122 (operation 2000). Portion 120 of object 104 may then be positioned relative to platform 108 using positioning system 124 associated with support structure 122 (operation 2002). Thereafter, portion 120 of object 104 may be moved towards platform 108 using retention system 126 in a manner such that portion 120 of object 104 substantially conforms to a shape of a corresponding portion of platform 108 to which portion 120 of object 104 is to be attached (operation 2004), with the process terminating thereafter.

With reference now to FIG. 21, an illustration of a process for supporting and loading a wing skin underneath a wing box is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in FIG. 20 may be implemented using modular support system 102 in FIG. 1 to support and load wing skin 112 underneath wing box 113 from FIG. 1.

The process may begin by supporting wing skin 112 on the support structure of each of number of support modules 114 in modular support system 102 by retaining wing skin 112 using the retention system of each of number of support modules 114 (operation 2100). Next, wing skin 112 is positioned to selected position 106 underneath wing box 113 using the positioning system associated with each of number of support modules 114 (operation 2102).

Thereafter, wing skin 112 is moved towards wing box 113 until wing skin 112 substantially conforms to a shape of wing box 113 using the retention system of each of number of support modules 114 (operation 2104). Operation 2104 may be performed using positioning system 124. In other illustrative examples, movement of wing skin 112 may be aided using some other type of motorized device. Wing skin 112 is then attached to wing box 113 using a tool attached to the support structure of each of number of support modules 114 (operation 2106), with the process terminating thereafter.

In this manner, modular support system 102 from FIG. 1 may be used to install wing skins for aircraft. Further, modular support system 102 may also be used to transport wing skins between facilities during manufacturing.

With reference now to FIG. 22, an illustration of a process for transporting and loading an object to a platform in a flexible manufacturing environment is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in FIG. 22 may be implemented using modular support system 102 in FIG. 1. Modular support system 102 may be used to transport and load object 104 to platform 108 within flexible manufacturing environment 101.

The process may begin by supporting object 104 using number of support modules 114 that are reconfigurable and capable of supporting objects of varying shapes, sizes, and contours (operation 2200). Next, number of support modules 114 may be moved within flexible manufacturing environment 101 to transport object 104 to selected position 106 underneath platform 108 (operation 2202).

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Thereafter, object 104 may be raised upwards to platform 108 using number of support modules 114 until object 104 substantially conforms to a contour of platform 108 (operation 2204). Number of operations 152 may then be performed on at least one of object 104 and platform 108 using at least one tool integrated with number of support modules 114, while object 104 is being supported by number of support modules 114 (operation 2206), with the process terminating thereafter.

With reference now to FIG. 23, an illustration of a process for transporting and loading wing skins to wing boxes is depicted in the form of a flowchart in accordance with an illustrative embodiment. The process illustrated in FIG. 23 may be implemented using modular support system 102 in FIG. 1. In particular, the process may be used to transport and load wing skins, such as wing skin 112, to wing boxes, such as wing box 113.

The process may begin by moving number of support modules 114 that are supporting a first wing skin on top of number of support modules 114 to transport the first wing skin to a first selected position underneath a first wing box (operation 2300). The first wing skin may be raised upwards to the first wing box using number of support modules 114 until the first wing skin substantially conforms to a first contour of the first wing box to load the first wing skin to the first wing box (operation 2302).

The first wing skin may be secured to the first wing box using at least one tool integrated with number of support modules (operation 2304). Number of support modules 114 may be moved away from the first wing skin once the first wing skin has been secured to the first wing box (operation 2306). Thereafter, number of support modules 114 may be reconfigured to form a modified number of support modules that is configured to support a second wing skin for a second wing box (operation 2308), with the process terminating thereafter. The modified number of support modules may then be used to support, transport, and load the second wing skin to the second wing box.

The second wing skin may have at least one of a different shape, a different size, or a different contour than the first wing skin. Further, the second wing skin may have a different contour than the first wing skin.

Illustrative embodiments of the disclosure may be described in the context of aircraft manufacturing and service method 2400 as shown in FIG. 24 and aircraft 2500 as shown in FIG. 25. Turning first to FIG. 24, an illustration of an aircraft manufacturing and service method is depicted in the form of a flowchart in accordance with an illustrative embodiment. During pre-production, aircraft manufacturing and service method 2400 may include specification and design 2402 of aircraft 2500 in FIG. 25 and material procurement 2404.

During production, component and subassembly manufacturing 2406 and system integration 2408 of aircraft 2500 in FIG. 25 takes place. Thereafter, aircraft 2500 in FIG. 25 may go through certification and delivery 2410 in order to be placed in service 2412. While in service 2412 by a customer, aircraft 2500 in FIG. 25 is scheduled for routine maintenance and service 2414, which may include modification, reconfiguration, refurbishment, and other maintenance or service.

Each of the processes of aircraft manufacturing and service method 2400 may be performed or carried out by a system integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-

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system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, a leasing company, a military entity, a service organization, and so on.

With reference now to FIG. 25, an illustration of an aircraft is depicted in the form of a block diagram in which an illustrative embodiment may be implemented. In this example, aircraft 2500 is produced by aircraft manufacturing and service method 2400 in FIG. 24 and may include airframe 2502 with plurality of systems 2504 and interior 2506. Examples of systems 2504 include one or more of propulsion system 2508, electrical system 2510, hydraulic system 2512, and environmental system 2514. Any number of other systems may be included. Although an aerospace example is shown, different illustrative embodiments may be applied to other industries, such as the automotive industry.

Apparatuses and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method 2400 in FIG. 24. In particular, modular support system 102 from FIG. 1 may be used for transporting, supporting, and loading a wing skin for a wing of aircraft 2500 during aircraft manufacturing and service method 2400. For example, without limitation, modular support system 102 may be used during the component and subassembly manufacturing 2406, system integration 2408, routine maintenance and service 2414, or some other stage of aircraft manufacturing and service method 2400.

In one illustrative example, components or subassemblies produced in component and subassembly manufacturing 2406 in FIG. 24 may be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft 2500 is in service 2412 in FIG. 24. As yet another example, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during production stages, such as component and subassembly manufacturing 2406 and system integration 2408 in FIG. 24. One or more apparatus embodiments, method embodiments, or a combination thereof may be utilized while aircraft 2500 is in service 2412 and/or during maintenance and service 2414 in FIG. 24. The use of a number of the different illustrative embodiments may substantially expedite the assembly of and/or reduce the cost of aircraft 2500.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams may represent a module, a segment, a function, and/or a portion of an operation or step.

In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

Thus, the illustrative embodiments provide a modular support system, such as modular support system 102 in FIG. 1 and modular support system 200 in FIG. 2, which may be used within a working environment, such as, for example, without limitation, a flexible manufacturing environment. Number of support modules 114 may be adjusted to support

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a variety of ribs to panel joining operations. A support module in number of support modules 114 may not be location-specific.

In other words, the support module may not only be configured for use in supporting a particular portion of an object, such as a wing skin. Rather, the support module may be reconfigurable and able to accommodate a variety of shapes, sizes, and/or contours. As a result, a fewer number of support modules may be needed within a working environment. With fewer support modules needed, modular support system 102 may provide a more ergonomically desirable working environment for human operators working within the working environment. Further, the adjustable nature of modular support system 102 may improve ergonomic access for human operators to perform operations under object 104 being supported by modular support system 102.

Additionally, modular support system 102 may have a low infrastructure system that may be used in a setting such as, for example, without limitation, a factory, without requiring costly floor installations, rails, tracks, and/or external jacks. More specifically, modular support system 102 may be used on a substantially smooth floor without any additional devices and/or structures.

Further, by integrating tooling with modular support system 102, tooling operations on object 104 supported by modular support system 102 and/or on platform 109 to which object 104 is being loaded may be performed more easily, more quickly, and more efficiently. The automated nature of modular support system 102 may be able to support counterbalanced manual tools and/or loading portable automated devices to local work zones.

The description of the different illustrative embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other desirable embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A method for supporting and loading a wing skin underneath a wing box, the method comprising:

supporting the wing skin on a support structure of each of a number of support modules in a modular support system by retaining the wing skin using a retention system of each of the number of support modules, wherein the number of support modules comprise a number of actuators and a number of tilt plates;

positioning the wing skin in a selected position underneath the wing box using a positioning system of each of the number of support modules;

moving the wing skin towards the wing box until the wing skin substantially conforms to a shape of the wing box using the retention system of each of the number of support modules wherein when the wing skin is moved upward by the number of actuators, the number of tilt plates rotate so that the wing skin substantially conforms to the shape of the wing box; and

attaching the wing skin to the wing box using a tool attached to the support structure of each of the number of support modules.

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2. The method of claim 1, wherein each of the number of support modules further comprise a number of gas springs and a number of suction cups movably affixed to the number of tilt plates.

3. The method of claim 2, wherein the number of suction cups are configured to adhere to a portion of the wing skin by applying at least one of a vacuum and negative pressure to the portion of the wing skin.

4. A method for transporting and loading an object to a platform in a flexible manufacturing environment, the method comprising:

supporting the object using a number of support modules that are reconfigurable and capable of supporting objects of varying shapes, sizes, and contours;

moving the number of support modules within the flexible manufacturing environment to transport the object to a selected position underneath the platform;

raising the object upwards to the platform using the number of support modules until the object substantially conforms to a contour of the platform wherein the number of support modules comprise a number of actuators and a number of tilt plates and wherein when the number of actuators raise the platform upward, one or more of the tilt plates rotate so that the object substantially conforms to a first contour of the platform; and

performing a number of operations on at least one of the object and the platform using at least one tool integrated with the number of support modules, while the object is being supported by the number of support modules;

wherein the platform is a wing box and the object is a wing skin.

5. The method of claim 4, wherein moving the number of support modules carrying the object comprises:

moving the number of support modules over a substantially smooth floor in the flexible manufacturing environment to transport the object to the selected position underneath the platform.

6. The method of claim 4, wherein supporting the object using the number of support modules comprises:

positioning each support module in the number of support modules such that each support module is configured to receive and support a designated portion of the object based on the number of operations to be performed.

7. The method of claim 4 further comprising:

moving the number of support modules away from the object once the object is secured to the platform.

8. The method of claim 7, wherein moving the number of support modules away from the object once the object is secured to the platform comprises:

moving the number of support modules away from the object once the object is secured to the platform in a progressive manner such that a support module in the number of support modules is moved away from the object when a portion of the object being supported by the support module has been secured to the platform.

9. The method of claim 7 further comprising:

reconfiguring the number of support modules to support a new object to be loaded to a new platform, wherein the new object has a different contour compared to the object.

10. The method of claim 9, wherein reconfiguring the number of support modules comprises:

reconfiguring the number of support modules by at least one of changing a position of a support module in the

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number of support modules relative to other support modules in the number of support modules, replacing a support module in the number of support modules, altering a support module in the number of support modules, removing a support module from the number of support modules, or adding a new support module to the number of support modules.

11. The method of claim 4, wherein each of the number of support modules further comprise a number of gas springs and a number of suction cups movably affixed to the number of tilt plates.

12. The method of claim 11, wherein the number of suction cups are configured to adhere to a portion of the wing skin by applying at least one of a vacuum and negative pressure to the portion of the object.

13. A method for transporting and loading wing skins to wing boxes, the method comprising:

moving a number of support modules supporting a first wing skin on top of the number of support modules to transport the first wing skin to a first selected position underneath a first wing box in which the number of support modules are part of a modular support system that is reconfigurable;

raising the first wing skin upwards to the first wing box using the number of support modules until the first wing skin substantially conforms to a first contour of the first wing box to load the first wing skin to the first wing box, wherein the number of support modules comprise a number of actuators and a number of tilt plates and wherein when the number of actuators raise the first wing box upward, the number of tilt plates rotate so that the first wing skin substantially conforms to a first contour of the first wing box;

securing the first wing skin to the first wing box using at least one tool integrated with the number of support modules;

moving the number of support modules away from the first wing skin once the first wing skin has been secured to the first wing box; and

reconfiguring the number of support modules to form a modified number of support modules that is configured to support a second wing skin for a second wing box.

14. The method of claim 13 further comprising:

receiving the second wing skin on the top of the modified number of support modules;

moving the modified number of support modules to transport the second wing skin to a second selected position underneath the second wing box; and

raising the second wing skin upwards to the second wing box using the modified number of support modules until the second wing skin substantially conforms to a second contour of the second wing box to load the second wing skin to the second wing box in which the second contour of the second wing box is different from the first contour of the first wing box.

15. The method of claim 13, wherein reconfiguring the number of support modules to form the modified number of support modules that is configured to support the second wing skin for the second wing box comprises:

reconfiguring the number of support modules to form the modified number of support modules that is configured to support the second wing skin for the second wing box, wherein the first wing skin and the second wing skin have at least one of a different shape, a different size, or a different contour.